IMPERIAL BUREAU OF ANIMAL NUTRITION

Technical Communication No. 11

SPROUTED FODDER AND GERMINATED GRAIN IN STOCK FEEDING

BY

I. LEITCH, M.A., D.Sc.
Imperial Bureau of Animal Nutrition

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INTRODUCTION.

THE present lively interest in sprouted fodder has arisen from the commercial exploitation of processes of water culture of plants to produce stock fodder. Different claims are made to have originated the idea and perfected the technique.

The best known is that of Spangenberg, whose name is commonly associated with the process of preparing sprouted fodder. His aims are set forth in the patent specification (first dated 1930) which is printed, with comments, as Appendix I. " . . . it will permit, by rapid artificial cultivation, to produce food plants for man or beast, which are of great value to the organism. . . . The invention is of very great importance for producing feeding stuff. Regardless of the time of the year, fresh green fodder will be available whenever desired, so that it becomes possible to dispense entirely with hay as fodder which readily gets mouldy when stored and thus may cause disease. . . . Hospitals or dietetic establishments in particular will be capable of producing on their own premises for dietetic treatment fresh vegetable foodstuffs containing certain nutritive or curative substances, such as iodine, and will be able to control the process completely."

Another patent claims the idea on behalf of Dr. von Skrbensky, a bacteriologist in German S.W. Africa, who, twenty-five years ago, evolved the system as a means of combating deficiency disease in stock. Although the deficient substances were inorganic and required only in " minute traces," they were, it is stated, not assimilated to the greatest advantage when given in inorganic form, but must be translated into organic form to be fully utilised.

The patent specification for this process is shown in Appendix II.

German investigators (40) dispute other claims and attribute the invention to one von der Kammer, who thought of it 30 years ago.

Justifiable claims to originality or priority can, of course, be made in respect only of the idea of large scale production of seedlings as fodder. The principles involved have been taught by botanists and

plant physiologists for over 70 years, and are included in all standard works on these subjects and on general biology. They are being applied to the greenhouse production of flowers and food plants, such as tomatoes, without soil (aquaculture, hydroponics) (21, 46).

There are two British patents by Intensive Cultivations, Ltd., " Cabinet Culture " or " Crop-a-day " (Spangenberg), and by Sprout, Ltd., " The Sprout Process " (Skrbensky). These differ in detail, as explained below.

There are two similar German patents, supplied by Ihrke and Koch, and by " Winterweide," Berlin. In Australia an electrically heated cabinet, Vitaplant, is marketed by " British Cultivations, Ltd."

DESCRIPTION OF PATENTED PROCESSES.

EQUIPMENT AND TECHNIQUE.*

The equipment consists of cabinets, built in uniform unit sections, with shallow tank shelves and removable perforated trays. The seeds are sown in these perforated trays, irrigated on a prescribed plan by nutrient solution from a tank on the roof and drained by pipes. The Cabinet Culture Standard Unit, which is of galvanised iron, provides for a ten-day rotation, one section being sown and one harvested each day with an approximate daily yield of 200 lb. fodder. The Sprout Process Unit of wood and glass, with galvanised iron shutters and trays, gives 160 lb. daily, also with a ten-day rotation.

According to the patent specification (Appendix I) somewhat different nutrient solutions are recommended for different seeds. It appears, however, that each firm markets only one.

" Cabinet Culture " advises the use of 6 lb. " ordinary commercial grain (maize, barley, oats, etc.) " per tray, i.e. 48 lb. seed to start a standard unit. This is soaked for 24 hours in the bottom shelf and then removed to another shelf on which it is irrigated by turning on the tank tap for 3 minutes daily. At the end of the tenth day the sprouts are ready for use. The cabinet is heated by a small oil burner. The work is said to take only three-quarters of an hour daily.

This is the description from the firm's advertisement.* That from The National Institute for Research in Dairying, Reading (34), using an early model, is considerably more complicated, including flooding and draining of the trays at stated intervals, involving daily attention at three separate times, and the cleaning of the trays before refilling, which is necessary to control the growth of mould. The total time of one man averaged a little over two hours daily, but it was thought that a saving in time would be effected with a larger installation.

The " Sprout Process " unit cabinet has 4 trays, each taking 10 lb.

* The description given here refers to the cabinets and technique as advertised up to the end of 1937 or as used in the experimental feeding tests to be discussed. We are informed that the patentees have made certain improvements in structure, but, as far as we know, no report has yet been published of practical feeding tests in which the newest type of cabinet has been used.

seed. It is heated by a built-in stove and boiler. The work of sowing, irrigation and attending to the heating, for an installation of two such units, is said to take 2½ hours daily. The report from Auchincruive (37), however, emphasises strongly the need for careful attention to the routine of irrigation and for scrupulous cleanliness.

This type of cabinet has glass windows with metal shutters so that light may be admitted or excluded as desired.

The electrically heated cabinet used at Hawkesbury College, N.S.W. (11), is similar in general structure to the Cabinet Culture unit. Difficulty was experienced from uneven flooding of the compartments and from the development of mould and accumulation of slime, in spite of the use of formalin in the irrigating solution. Internal illumination is provided in this cabinet for greening the shoots in the later stages of growth.

The Wye (48, 50) and Berlin (38-43) reports give no details as to equipment in the installations used.

THE SEED.

Cabinet Culture states specifically that " ordinary commercial grain " is to be used. The Reading report (34) states that the germinating capacity of commercial maize, as determined in special tests, averages about 70 per cent. Seed maize has a germinating capacity of about 96 per cent., but the price is prohibitive. Conditions at Reading were apparently not favourable to germination. The average for commercial maize was from 60 to 65 per cent. and high grade seed maize did no better. Increasing the amount of maize per tray to 10 lb. reduced percentage germination to from 40-50 and so gave little increase in density of crop. (See also below, pp. 9, 10 : Yield.)

In later experiments at Reading, with the Sprout Process, a germination of only 33 per cent. was found from maize of about 66 per cent. germinating capacity.

The Auchincruive report (37) (Sprout Process) states that an average germination of 70 per cent. was found.

The Spangenberg patent specification talks of irradiating the seed by " quartz lamp " for 3 to 10 seconds to promote germination, but neither of these commercial firms makes any mention of such treatment.

In this connection and for yield of fodder also, it may be of significance that the trays used in commercial equipment are of galvanised iron. It is possible that zinc salts may be formed which are toxic to

the seedlings. Templeton and Watson (46) say of water cultures: "On no account should untreated galvanised iron tanks be used, as they may give rise to zinc poisoning."

THE NUTRIENT SOLUTIONS.

The composition of the nutrient mixtures sold, to be diluted with water and used in the cabinets, is indicated in the patent specifications. There is, however, no evidence to show that they produce results superior to what would be expected from standard water culture solutions.

A standard solution is shown in the comments, Appendix I, for comparison with the indications given in the patent specifications.

A culture solution, prepared from commercial salts bought in bulk, would probably be as cheap as, or cheaper than, the patented solutions.

At Hawkesbury College (11) trials in which the drainage water was used to irrigate field plots of lettuce and other vegetables showed significant responses and some economy in practice might be effected in this way.

WATER CONSUMPTION.

It has been suggested that this method of producing fodder would be of value in areas where water shortage occurs. But unless the fodder is shown to have definite advantages, other than its succulence, over unsprouted grain, there would be a considerable waste of water. In the first Reading experiments the consumption of water daily was 700 gallons for 10 shelves of seedlings. That means, with a 10-day rotation, a consumption of 700 gallons of water for the fodder produce of 1 shelf, which averaged about 160 lb. The water content of the fodder was roughly 85 per cent. and that of the dry maize about 14 per cent. Calculating, therefore, with an increase in water content of about 70 per cent., the yield of water in fodder was only 112 lb. from 7000 lb. in the nutrient solution.

In the second series, the yield of water was about 100 lb. in fodder from 4000 to 5000 lb. water in the nutrient solution.

CONTROL OF TEMPERATURE.

In order to procure the most rapid and uniform growth of the seedlings, giving crops (maize) of about 10 to 12 inches high in 10 days, regulation of the temperature to the level optimal for growth is advised.

The first Reading report states that no specific instructions were given with their cabinet, but only a general indication that about 80° F. (26·7° C.) was suitable. In summer, therefore, they provided no heating, but in winter found that considerable difficulty arose. The room in which the cabinet was worked had to be made free from draughts and an oil stove kept burning. The temperature of the irrigating water had to be carefully regulated and injury was caused by using water at 95° to 100° F. (35° to 36·7° C.). In addition the heat generated by the growing seedlings themselves gave temperatures in trays of 8-day growth 10° to 15° F. (5·6° to 8·3° C.) above those in freshly spread trays. In the second series of experiments the temperature was maintained at about 75° F. (24° C.).

At Auchincruive the Sprout unit, although heated by attached boiler and anthracite or coke stove, also gave trouble. The temperature desired for maize was to be not less than 70° F. (21·1° C.) and not as high as 90° F. (32·2° C.). Lower temperatures, 60° to 70° F. (15·2° to 21·1° C.) are recommended for oats and barley, which would make it practically impossible to grow these along with maize. One unit which was erected in a somewhat exposed position had to have protecting enclosures built round it to make temperature regulation possible.

The electrically heated cabinet, with thermostat control, at Hawkesbury College was no more satisfactory. Temperature varied from 70° F. (21·1° C.) at the top to 100° F. (36·7° C.) at the foot, close to the heating units, and also varied with outside temperature. The result was patchy germination and growth, and a fall in yield with rise of temperature above that for which the thermostat was set.

These difficulties are, in part, what would be expected from a knowledge of plant physiology. It has been shown (28) that the optimum temperature for growth of pea seedlings is about 29° C., that temperatures above 30° C. are immediately detrimental to growth and that the effect increases with time of exposure. Since allowance must be made for the rise of temperature due to the growth process itself, under conditions of low ventilation and crowding such as existed in these cabinet cultures, it is clear that a general temperature too near the optimum must not be maintained and that irrigating water at a high temperature must be avoided. (The latter difficulty is not inherent in the technique but arose from the manner of fitting at Reading, the hot water being laid on from an outside heating installation. The water should be conditioned in the tank at the temperature of the cabinet.)

On the other hand, if uniform growth is demanded, the cost of ensuring the necessary insulation, in addition to heating, must be remembered when assessing cost of production.

LIGHT.

Cabinet Culture excludes light and therefore yields a crop of etiolated yellow seedlings. The Sprout Process provides shutters to control lighting and the Vitaplant internal illumination. The Auchincruive report says, however, that it is doubtful whether there is any advantage in admitting light at any stage. If a green crop is desired light is admitted after five days. But the green crop did not appear to be more palatable or of higher feeding value than the yellow.

It must, however, be remembered that no processes of photosynthesis can proceed in the etiolated leaf, and unless chlorophyll formation is allowed, the only constructive processes which can take place in the plant are such as can proceed at the expense of the food supplied by the seed and the culture solution.

THE CROP.

YIELD.

Cabinet Culture claims in ten days a crop of 200 lb. of succulent fodder from 48 lb. dry seed; Sprout Process, 40 lb. from each tray sown with 10 lb. In the Reading experiments, the yield did not reach the advertised standard but averaged under 168 lb. from 48 lb. dry seed in the first series, and between 14 and 22 lb. from 8 lb. dry maize in the second series. At Auchincruive the amount of seed used varied from 8 to 10 lb. per tray, according to the percentage germination expected, and the yield "should be at least three and a half times the original weight of seed used—i.e. from 28 to 35 lb.—and a yield of fourfold, 32 to 40 lb. is not impossible of attainment." The average yield in the feeding experiments is not recorded, but in the digestibility trials described by McCandlish and Struthers (32), the average yield of 14 trays from 8 lb. dry maize per tray was 26·58 lb., which is slightly less than the average at Reading.

Schmidt and Kliesch in Berlin (38, 43), using barley, found an average yield of 3·8 kg. fodder from 1 kg. barley seed.

At Hawkesbury College, the average yield (maize) of fresh fodder was two and a half times the weight of seed used to produce it in a "normal" six-day growth period, or 3·8 times the seed weight in a seven- or eight-day period. Reduction of the seeding rate by 25 per cent., i.e. from 8 lb. to 6 lb. per tray, reduced the crop yield by only 17·1 per cent. Hence a saving in seed cost per ton of fodder would be effected by reducing the seeding rate. But since the time to produce a ton of fodder would be increased, with increases in charges for heating and labour, little, if any, reduction in total cost of production would be effected.

Experiments were also made at Hawkesbury with other crops, using suitable seeding weights, and the following weight ratios of fodder to seed (as 1) were found: barley, 3·2; wheat, 2·8; rye, 3; Japanese millet, 9; field peas, 7; sorghum, 6·5.

CHANGES IN COMPOSITION OF PLANTS DURING GERMINATION AND EARLY GROWTH.

Proximate Principles.

The general nature of the changes occurring during the germination of seed and the early growth of the seedling is well established (33). Absorption of water is first required. This is followed by rupture of the seed-coat, by the secretion from the cellular layer of the scutellum, which surrounds the embryo, of diastatic, proteolytic and lipolytic enzymes which prepare the stored material for transport to and use by the growing embryo. A large proportion of the transported carbohydrate and probably of the fat is burnt to provide the energy for growth and so a loss of dry matter occurs. This is, to a small extent, made good by absorption of nitrogen from the culture solution. In spite of this absorption of nitrogen and synthesis of protein in the seedling, a net loss of protein during the early stages of growth seems commonly to occur.

The proportion of the stored material used varies with the type of seed and the duration of growth in water culture. All of it is seldom, if ever, used, and in a 10-day growth period, with the seeds used in these fodder cultures, the proportion is low. For instance, in the barley experiments described below (43), the shoots constituted 11·9, the roots 1·6 and the seed 86·5 per cent. by weight of the crop. Since the water content of the growing part would probably be higher than

that of the seed, it follows that not less than 86 per cent. of the food material of the crop is still seed matter. And, indeed, it has already been noted that, of the seed "sown," 30 per cent. or more does not germinate.

Minerals.

Translocation of minerals from seed to embryo also occurs. The seed, however, does not contain a supply of minerals sufficient for the growth of the plant to maturity and the culture solution must provide additional supplies. In comparison with water alone, the rate of growth of the seedling is accelerated by a suitable culture solution.

The composition of the growing plant, in respect of inorganic elements, depends to some extent on the supply, but the differences which may be induced are, in practice, not important compared with the natural differences between species or even different parts of the same plant. Phosphorus, calcium, magnesium and iron can be varied, but within relatively narrow limits only. Some constituents, such as iodine, which are readily absorbed by the plant without toxic effects, may be greatly increased. Others, like boron, although traces of them appear to be essential to the plant, cannot be much increased without causing injury or death ; or, like manganese, may be increased, without obvious injury to the plant, to a level at which they are toxic to animals.

Vitamins.

No information has been found to show that the vitamin A value of seeds is changed during germination. Coward and Drummond (13) found no increase in etiolated seedlings and concluded that vitamin A is synthesised only in the presence of chlorophyll. There will probably be an increase where the seedlings are green.

A single study (22) of the vitamin B_1 content of germinated and ungerminated beans (black gram) shows that there is a loss on germination (*cf.* below, p. 18, occurrence of symptoms of beriberi in rats fed on milk from cows receiving sprouted maize).

In contrast with this, the riboflavin (a constituent of the vitamin B_2 complex) content of barley, oats and peas has been found to increase on germination (17). A maximum value, about 20 times the original, is reached in 2 days, and thereafter the riboflavin content remains steady up to 8 days, or declines slowly. The seedlings in these experiments were grown in light. There is no information to show whether similar increases occur in etiolated seedlings.

It is generally accepted that germination is accompanied by synthesis of vitamin C (ascorbic acid). Recent studies may be compared in the table compiled by Fixsen and Roscoe (20). Considerable increases have been found in some cereals, oat seedlings of 9 days' growth, for instance, giving ten times the value on the first day of germination (9). Most of the ascorbic acid is in the seedling. The increases in legumes appear to be relatively less (1).

The germ of wheat is a very rich source of vitamin E and the same is true at least of some other cereal embryos, maize and rice (5). No published information has been found to show whether a change takes place during germination, but since the green plant is relatively a less potent source of the vitamin than is the germ, it seems unlikely that there should be an increase in total vitamin E content. A private communication from Evans some years ago stated that he had found no vitamin E in sprouted oats (29).

COMPOSITION AS RECORDED DURING FEEDING TESTS.

The composition of the crop, as determined during feeding tests, is such as would be expected from the statement above. The imbibition of water during the swelling process and absorption by the growing embryo give the increase in weight ; a net loss of dry matter occurs, due to the respiration of the plant, and compensated only to a small extent by the absorption of salts from the culture medium. The results reported are shown below.

Percentage Composition of Sprouted Maize Fodder (10 Days) Compared with Corresponding Dry Seed.

	Reading (34).		Auchincruive.			Wye (48).
	Dry.	Sprouted.	Dry.	Sprouted. (32).	Sprouted. (37).	Sprouted.
			(*a*)	(*a*)	(*b*)	
Moisture . .	13·9	84·6	13·17	75·76	77·64	71·92
Dry matter . .	86·1	15·2	86·83	24·24	22·36	28·08
Organic matter .	—	—	85·57	23·67	—	—
Crude protein .	8·3	2·2	9·89	3·59	3·05	3·56
True protein . .	8·3	2·0	9·58	2·68	—	2·12
Sol. CHO . .	—	—	69·50	17·69	16·67	—
Crude fibre . .	—	—	1·60	1·23	1·10	—
Fat . . .	—	—	4·58	1·16	1·02	—
Ash . . .	0·89	0·47	1·26	0·57	0·52	—

The Reading analyses (34) are presented for each day of growth, showing a gradual fall of total dry matter (22 per cent. loss). This loss is entirely of carbohydrate. There is, in fact, a slight gain in crude protein with no loss of true protein.

From their analyses (Auchincruive (*a*)) McCandlish and Struthers (32) show the following percentage gains or losses when maize is sprouted : total weight, + 232 ; moisture, + 1918 ; dry matter, — 7 ; organic matter, — 8 ; crude protein, + 20 ; true protein, — 8 ; soluble carbohydrates, — 15 ; crude fibre, + 154 ; fat, — 16 ; ash, + 50.

In the Hawkesbury College tests (11), 100 lb. of maize seed (89 lb. dry matter) gave roughly 300 lb. fodder, with a dry weight of 63 lb., i.e. a dry matter loss of nearly 30 per cent. The percentage moisture in the fodder was 79, fat 1·13, crude protein 2·38 and carbohydrates 16·95.

It will be seen that there is a considerable range of variation in these analyses. For instance, dry matter of sprouted fodder varies from 15·2 per cent. at Reading to 28·08 per cent. at Wye. This is certainly due chiefly to differences in the amount of growth secured. The Reading and Auchincruive crops were both of 10 days' growth, but the former must have been further advanced. The Wye report does not say how many days' growth is represented but says that the temperature was badly regulated and growth uneven and sometimes poor.

Only Reading reports on changes in ash content. In their experiments, total ash, as a percentage of dry matter, increased during the ten-day growth period from 1·03 to 3·06 ; calcium (as CaO) from 0·023 to 0·138, and phosphorus (as P_2O_5) from 0·730 to 1·237.

In the German experiments with barley, the first analyses (*a*) (mean of two samples) of fodder, with leaves 10 to 15 cm. long, and yellow-green in colour, showed the following changes in percentage composition : crude protein, + 7·6 ; true protein, — 7·8 ; fat, — 33·8 ; carbohydrate, — 31·2 ; fibre, + 533·3. This means a loss of digestible protein of 13·2 per cent. and of starch equivalent of 28·3 per cent.

In the second series (*c*), in which the leaves were green and development for 10 days, the losses were even greater : 30 per cent. of digestible protein and 45 per cent. of starch equivalent.

Analyses (*b*) (six days' growth), (*d*) and (*e*) (ten days' growth) are from comparable series where analyses were made daily. Comparison of these shows that the culture solution has a stimulating effect on growth (*d* and *e*) and that the losses are progressive with growth.

PERCENTAGE COMPOSITION OF SPROUTED BARLEY FODDER COMPARED WITH CORRESPONDING DRY SEED: BERLIN (37).

	Dry.		Sprouted.				
			With Nutrient Solution.				Without Nutrient Solution.
	(*a*)	(*b*)	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)
Moisture . . .	10·8	11·59	—	80·3	86·09	84·4	66·4
Dry matter . .	89·2	88·41	—	19·7	13·91	15·6	33·6
Organic matter .	86·6	85·83	—	19·0	13·25	15·2	32·7
Crude protein . .	8·3	10·12	3·37	3·1	1·78	2·0	3·7
True protein . .	7·7	8·81	2·66	2·7	1·37	1·7	3·0
Sol. CHO . .	73·1	70·32	11·95	13·4	8·95	9·9	25·0
Crude fibre . .	2·9	3·56	1·80	1·7	2·07	2·6	3·2
Fat.	2·3	1·83	0·64	0·7	0·55	0·6	0·8
Ash	2·6	2·58	—	0·7	0·56	0·7	0·9

FEEDING EXPERIMENTS.

THE EFFECT OF COMMERCIAL PROCESS SPROUT FODDER ON MILK PRODUCTION, GROWTH AND FATTENING.

Feeding experiments are of two main types: (*a*) those in which sprouted maize fodder on an equivalent or approximately equivalent dry matter basis has replaced another succulent fodder in normal rations, and (*b*) those in which dry barley or part of the dry barley in a ration has been replaced by sprouted barley produced from an equivalent weight of seed. It is possible in principle to argue in favour of both methods. It is obvious that, with the losses of dry matter, protein and starch equivalent recorded above, the scales are weighted against the fodder in the second type. The results of both might have been more convincing if the methods had been combined; that is, if the first had included control feeding of an amount of dry seed equivalent to that from which the fodder was grown and the second sprouted fodder equivalent on a dry matter basis to the seed replaced.

Dairy Cows.

Tests have been made with sprouted maize at the National Institute for Research in Dairying at Reading and at the South Eastern Agricultural College, Wye. One test with sprouted barley is reported from the Institute of Animal Breeding, the University, Berlin.

Reading.

1. The first test (34) was made in summer 1933 with 2 groups, each of 5 cows, which were not evenly matched because of their advanced stage of lactation. The cows were run on pasture which was parched and bare. In addition to a basal ration, controls were given 28 lb. vetch and oat silage ; experimental, the fodder from 6 lb. dry maize daily. The general nutrient values of the rations were closely similar. The preliminary period was two weeks and the experimental five.

The results are calculated in this way : taking the average pre-experimental yield in the silage group as 100 (actual yield, 205·45 lb., experimental, 159·80 lb. weekly) the differences between the gains or losses in each subsequent week are expressed as a percentage. For instance :

Control group, first week	− 5·98 lb.
Sprout group, ,, ,, ...	+ 1·45 ,,
Advantage of sprout group	+ 7·43 lb.
Production value of sprout group when control = 100	103·93

The total results are summarised thus :

Sprouted maize group compared with silage group = 100.

Week.	1.	2.	3.	4.	5.
Milk yield . . .	103·9	110·4	112·0	103·6	104·9
Fat per cent. . .	99·2	100·1	100·4	104·8	105·1
Solids-not-fat, per cent.	100·9	101·1	101·7	101·7	101·8

Liveweight gains in the control group averaged 1 lb. and in the sprouted maize group 32 lb. in 5 weeks.

The second experiment followed in September and October of the same year. In it a ration of 21 lb. silage and 6 lb. sprouted maize was compared with one of 10 lb. meadow hay and 35 lb. kale, 5 cows in each group.

The third test, on two groups, each of 6 cows, came a month afterwards, from November 5th, when there was still pasture available, to January 14th. The basal ration was of hay 7 lb. (later increased to 12 lb.) and kale 35 lb. with a production ration of 2 lb. concentrates for the first gallon of milk and $3\frac{1}{2}$ lb. for each further gallon. In the experimental period of 6 weeks, the kale was replaced by sprouted fodder, 8 lb. (dry weight) replacing the kale for the first half of the time, and 12 lb. (dry weight) replacing 35 lb. kale and 2 lb. maize germ meal.

The results of the second experiment are so like those of the first that it is unnecessary to present further tables: those of the third experiment averaged only about 90 per cent. of the controls, for milk yield, but were similar in other details. It is impossible to draw any conclusion from the three except that sprout fodder appears to be as good as the fodder it replaced.

Estimates were made of the yellow colour, the blue value and the ascorbic acid content of the milks in the last experiment. The results were "normal" for both groups and showed no significant difference.

The conclusion from these tests was that sprouted fodder possesses no special feeding value. "The chemical composition of sprouted maize, therefore, provides a reliable criterion of its food value."

2. The second series of tests (8) was begun in December 1936 with 4 groups, each of 3 cows, the groups matched as evenly as possible. During a preliminary period of 5 weeks all were given mangels, at the rate of 42 lb. daily to each cow, in addition to a basal ration of hay and concentrates. For the next 11 weeks one group was continued on mangels; the second was given daily 46 lb. of thousand-headed kale; the third, 14 lb. of artificially dried grass and the fourth, sprout fodder from 4 lb. of dry maize. This experimental period was followed by a second control period of 6 weeks on mangels and a final period of 2 weeks on pasture. The experimental supplements were planned as reasonable under practical conditions and the rations were balanced by adjustment of the quantities of hay and concentrates to provide about 13 lb. starch equivalent and 2 lb. protein per head. Additional concentrates were fed when the milk yield exceeded 2 gallons daily.

In calculating average milk yields, the first two weeks of the experimental period and the first week of the second control period were omitted. The average milk yields during the experimental period, expressed as a percentage of the mean yields in the two control periods, were:

Mangels 102·3; kale 107·4; artificially dried grass 107·1; and sprouted maize 104·3.

Expressed in the same way, the fat content and solids-not-fat of the milks are shown as follows:

Fat: Mangels 103; kale 107; dried grass 101; sprouted maize 100.

Solids-not-fat: Mangels 100; kale 99; dried grass 100; sprouted maize 99.

The differences in yield and composition were, therefore, negligible.

The average increments or losses in weight of the cows, as compared with the weights at the end of the first control period, are recorded.

	After 8 *weeks*	*After* 11 *weeks*	4 *weeks later*
Mangels . . .	+ 15 lb.	+ 19 lb.	+ 18 lb.
Kale	+ 1 lb.	+ 32 lb.	+ 19 lb.
Dried grass . .	+ 41 lb.	+ 53 lb.	+ 50 lb.
Sprouted maize . .	— 54 lb.	— 3 lb.	+ 21 lb.

The loss of weight in the sprouted maize group is attributed to unpalatability of the fodder "owing to makeshift arrangements for its production through delay in delivery of the complete plant. When improvements had been made in the quality . . . the live weight gains made by the cows compared satisfactorily with those fed other supplements."

Estimates were also made of the vitamin values of the milk from each group.

Vitamin A and carotene.—Vitamin A and carotene were estimated by physical and chemical methods in butters made at the end of the first control period and each week, using pooled daily samples of milk, throughout the rest of the test period.

The four groups started even. The mangel and sprouted maize groups continued to give closely similar values for both vitamin A and carotene, and showed little change during experimental feeding. But the kale and dried grass groups gave values about twice as high as those of the controls and their own initial levels.

Vitamin B complex.—Estimates of the total vitamin B complex by Kon's method, and of a part of the vitamin B_2 complex, including lactoflavin and possibly other constituents, were made by experiments on rats. Milks from the control, dried grass and sprouted maize groups were used.

In this case, no determinations were made during the control

period, so that the results show only the values of the milks during the experimental feeding and there is no certainty that the differences were due to the feeding.

As judged by rate of growth, there was no difference in content of the whole vitamin B complex between the milks from the three groups, but two of the eight rats in the group receiving milk from the cows fed on sprouted maize showed symptoms of beriberi. The sprouted maize milk also showed a significant deficit in vitamin B_2 complex as compared with the other two. It is of interest to compare the statement on p. 11. According to direct estimates on the plant, vitamin B_1 decreases and riboflavin increases during germination.

Vitamin C.—Total and reduced ascorbic acid were estimated in mixed samples of milk from all four groups. The differences were not great, but the sprouted maize milk contained significantly more reduced ascorbic acid than any of the others, and significantly more total ascorbic acid than milk from either the control or dried grass group. Although these differences were statistically significant, it is pointed out that they may have been due to differences in the cows and not to the effect of feeding. The difference between sprouted maize and control milks was also so small (0·171 mg. ascorbic acid or 3·42 I.U. of vitamin C per 100 ml.) as to be of no practical importance in human diet.

Value for growth.—Growth experiments were also made in which the milks were fed, supplemented with minerals or minerals and sugar, as the sole food to rats after weaning. No differences were found between the three milks tested, namely, those from the control, dried grass and sprouted maize groups of cows.

From these experiments, it appears that the feeding of sprouted maize showed no advantage in either milk yield or quality of milk.

Wye.

1. This trial (50) was begun with two groups, each of 9 cows, comparable as to liveweight, stage of lactation and age. Unfortunately the experiment had to be abandoned at the end of three weeks on account of scouring, which was particularly bad in the group receiving sprouted maize. During the three weeks of the trial, the basal ration was 12 lb. hay and 3 lb. concentrates per gallon of milk. One group had in addition 10 lb. sprouted maize and the other 40 lb. mangels and $\frac{1}{2}$ lb. decorticated ground nut cake. Milk yields were 4632 and 4687 lb.; liveweight changes, + 170 and — 34 lb.

2. In this experiment (48) 12 cows in three groups of 4 were used. They had a pre-experimental period of 3 weeks on the same diet of meadow hay (14-17 lb.) and silage of green pea haulm, a residue from the green pea canning industry (20 lb.), with 3 lb. of a concentrate mixture per gallon of milk. The composition of the concentrate-mixture was, parts: 1½ decorticated earth nut cake; ½ linseed cake; 4 flaked maize and 1 bran.

During the experimental period of 12 weeks, the silage was replaced by 10 lb. of sprout fodder for one group and the concentrate allowance was replaced by 3 lb. of dried grass, ⅓ lb. decorticated earth nut cake and ⅓ lb. crushed oats for another. The rations supplied almost equal amounts of digestible nutrients.

The average milk yields and changes in bodyweight are shown in the table below, the "adjusted" figures representing the result of statistical correction for the pre-experimental yields or weights:—

	Maize Sprout.	Dried Grass.	Control.
Average milk yield: lb. daily			
Pre-experimental . .	31·03	28·51	31·71
Experimental . . .	23·35	18·29	19·34
,, adjusted .	22·86	19·83	18·30
Av. gain or loss in bodyweight in experimental period: lb. .	+19·5	−14·5	+56·0
Av. gain or loss in bodyweight in experimental period: lb. adjusted	+19·58	−15·89	+57·14

The difference in milk yield between the sprout and control groups was almost statistically significant and, in view of the small number of animals in the tests, the authors regard this as suggestive. Other differences were not significant.

Berlin.

In introducing the report on this experiment (39), the authors state that the sprout patentees claim increases of 8 to 9 kg. daily in milk yield and increases in fat content of 3 per cent., from feeding sprouted fodder.

The test was with two groups, each of 4 cows, with a preliminary period on controlled uniform diet of 4 weeks and an experimental

period of 9 weeks. The basal diet was of 4 kg. meadow hay, 4 kg. lucerne hay, 4-5 kg. dried beet slices, 3·5-4·5 kg. concentrates and 0·5 kg. crushed barley. During the experimental period the crushed barley was replaced by 1·8 kg. sprouted fodder, the quantity (roughly) which would be grown from 0·5 kg. barley as seed. The results were as follows :—

	Control.	Sprout.
Av. milk yield : kg. daily		
Pre-experimental	22·2	21·9
Experimental	20·6	20·2
Av. gain in weight during experiment : kg.	19	22

There was no change in the percentage of fat in the milk. The only result, the authors say, was "a considerable increase in cost of the ration."

The results of all these tests may be summed up by saying that sprouted maize fodder of approximately equivalent nutritive value can replace silage or kale ; and that when a very small proportion of barley in a ration is replaced by the seed equivalent amount of sprout fodder, no evidence appears of the loss of dry matter during growth of the sprout. No evidence of any special virtue or effect was found.

A note in *The Farmer's Weekly, Bloemfontein* (51), on the other hand, claims that, once cows had been coaxed to eat sprouted maize, milk yield improved by just over 25 per cent. in about a week. As no particulars are given as to stock, rations or management, the significance of this claim cannot be assessed.

Hawkesbury College reports (10) that sprouted fodder is unpalatable to dairy cows but that they might acquire a taste for it.

Beef Cattle.

Auchincruive.

A series of 6 experiments (35, 36, 37) has been made at the West of Scotland College of Agriculture, Auchincruive, in which a total of 70 sprout-fed bullocks have been compared with 74 without sprout. The basal ration in these experiments was of concentrates (4 parts

crushed oats, 4 parts flaked maize, 2 parts decorticated earth nut cake, 1 part linseed cake), swedes, hay and straw. The sprout fed groups had 20 lb. or, in one experiment, 20 and 30 lb. and, in one, 10, 20, and 30 lb. of the swedes replaced by sprout fodder to give the equivalent of dry matter. Other groups which are included in the 74 controls received experimental rations in which dried grass replaced the concentrates, weight for weight.

The amounts of concentrates fed, for instance in experiment C on 28 bullocks, were 5½ lb. increasing to 8½ lb. (average 7 lb.) ; of swedes 54 lb. increasing to 66 lb. (average 60 lb.) ; of hay 10 lb. and of straw 6 lb. per head daily. In the other experiments the variations from this ration were insignificant.

On the average, the amount of dry matter fed daily was 26 lb. When sprouted fodder replaced swedes at the rate of 8 lb. for 20 lb. swedes,* giving 2 lb. dry matter, it supplied only 7·7 per cent. of the total dry matter of the ration. Further, since 30 per cent. of the seed remained ungerminated and only about 14 per cent. of the fresh weight of the crop is shoot, only about ¼ lb. or 1 per cent. of the dry matter was supplied by the shoots.

The results of the experiments are collected in the table on p. 22, and the average differences, which are uniformly in favour of sprout feeding, are summarised below:—

Summary of Differences.

Average liveweight gain : lb. daily—			
All sprout fed less all controls	2·62	2·23	0·39 lb.
20 lb. swede replacement only less basal ration controls	2·71	2·31	0·40 lb.
The same, excluding Experiment C	2·82	2·33	0·49 lb.
Sprout fed less controls, excluding dried grass	2·67	2·31	0·36 lb.
Sprout fed less controls, dried grass only	2·39	2·01	0·38 lb.

Condition and carcase weight.

Sprout fed bullocks in appearance showed a bloom which was evident after three or four weeks, and in which they resembled grass fattened animals.

Carcase weight averaged 55·5 per cent. of unfasted liveweight in control groups and 56 per cent. in those fed sprouted fodder.

* There are minor differences in statements made as to the amount of sprout fed. In one report (36) 8 lb. sprout is said to have replaced 20 lb. swedes ; in another (35) sprout to provide 2 lb. dry matter ; in the final summary (37) 9 lb. is said to have been fed in all the experiments.

Cattle Feeding Experiments: Auchincruive.

Experiment.	Control.				Sprout Fed.							
	Basal Ration.		Dried Grass Replacing Concentrates Weight for Weight.		Sprout of Equivalent Dry Matter Replacing Swedes in Amounts of: 10 lb.		20 lb.		30 lb.		Dried Grass Replacing Concentrates, Sprout Replacing 20 lb. Swedes.	
	No.	Av. Daily Gain: lb.	No.	Av. Daily Gain: lb.	No.	Av. Daily Gain: lb.	No.	Av. Daily Gain: lb.	No.	Av. Daily Gain: lb.	No.	Av. Daily Gain: lb.
A 12 weeks	12	2·57					4	3·11				
B 14 weeks	12	2·37					4	2·96				
C 12 weeks	10	2·23					10	2·46	8	2·40		
D 14 weeks	8	2·14	8	1·87			4	2·81			8	2·33
E 12 weeks	6	2·08	{6 6	{2.19 2·03}			6	2·58			4	2·50
F 12 weeks	6	2·25			8	2·81	6	2·77	8	2·60		
Av. duration all experiments, 12·7 weeks	Total 54	Mean 2·31	Total 20	Mean 2·01	Total 8	Mean 2·81	Total 34	Mean 2·71	Total 16	Mean 2·50	Total 12	Mean 2·39
Av. duration excluding C, 12·8 weeks	Total 44	Mean 2·33					Total 24	Mean 2·82				

Since the differences are uniformly in favour of sprout and of a significant size, it is natural to look for a possible explanation. Only one experiment to determine the effect of sprout on digestibility of the ration has been made.

McCandlish and Struthers (32), in association with the feeding tests just described, determined the digestibility of a similar ration with 2 bullocks, 1 year and 9 months old and weighing 977 and 940 lb. There were two feeding periods of 14 days each, the first on the standard ration of 7 lb. mixed hay, 7 lb. concentrates and 60 lb. mangels ; in the second, 20 lb. mangels were replaced by 6·15 lb. sprouted maize.

The following table shows the changes found :—

Percentage Digestibility of Standard and Sprout Ration.

	Standard.	Sprout.
Dry matter . . .	65·0	66·9
Organic matter . .	66·0	67·8
Crude protein . .	57·1	62·2
True protein . . .	53·4	59·1
Soluble carbohydrate .	72·0	73·6
Fat	72·5	78·0
Crude fibre . . .	48·7	47·7

There was an increase in digestibility for all constituents except fibre. The largest increase was for true protein. The increase for total dry matter was 1·9 per cent. only, and this was clearly insufficient to explain increases in rate of liveweight gain of from 15 to 20 per cent.

Schmidt and his co-workers (43), with reference to the pig fattening experiments described in the next section, discuss the possible role of increased digestibility in increasing gains, and conclude that, since the basal ration they used was 85 to 90 per cent. digestible, even if the sprouts were 100 per cent. digestible, there would be little improvement. This view is in agreement with the Auchincruive results.

Effect on quality of meat.

In addition to a material increase in rate of liveweight gain, sprout feeding at Auchincruive produced meat of "excellent appearance, singularly tender, and attractive to the palate."

Berlin.

The results of two fattening experiments with bullocks at the Koppehof (Berlin) Station (42), in contrast to the Glasgow tests, were negative.

The first was begun with 3 groups, each of 5 bullocks, which had been outwintered on pasture and were in poor condition. One of these had later to be removed from the test. They were fed during a pre-period of 8 weeks on a ration of steamed potatoes and meadow hay *ad lib.*, with ½ kg. soyabean meal. During the experimental period of 14 weeks, this ration was continued with the addition for the control group of 1 kg. daily of crushed barley. The two experimental groups were given the equivalent (seed weight) of sprouted barley, allowed for one group to grow for the usual period (4·1 kg.) and for the other fed at a length of 2-3 cm. (2·9 kg.). The results are shown below.

Cattle Feeding Experiment 1: Berlin.

	1. Barley.	2. Long Sprouts.	3. Short Sprouts.
No. in group	5	5	4
Av. initial wt., kg.	360	359	344
Av. final wt., kg.	445	445	432
Av. gain, kg.	85	86	88
Av. feeding time, days	98	98	98
Av. daily gain, g.	867	878	898
,, ,, lb.	1·91	1·93	1·98
Dig. prot. per kg. gain, g.	798	770	779
Starch equiv. per kg. gain, g.	6499	6229	6323

Cattle Feeding Experiment 2: Berlin.

	1. Barley.	2. Sprout.
No. in group	2	3
Av. initial wt., kg.	253	246
Av. final wt., kg.	363	348
Av. gain, kg.	110	102
Av. feeding time, days	119	119
Av. daily gain, g.	924	857
,, ,, lb.	2·03	1·89
Dig. prot. per kg. gain, g.	606	636
Starch equiv. per kg. gain, g.	4754	4987

The second test included 5 young bullocks on the same basal ration with 700 g. (instead of 1 kg.) barley or its equivalent as sprout fodder.

These results must be accepted as negative but it must be remembered that in feeding the sprout grown from a quantity of barley equivalent to that displaced, there is a reduction in total dry matter and protein of the ration.

Calves.

A report has just been published (31) on experiments in calf-rearing at the West of Scotland Agricultural College. It is relevant here to compare the three groups receiving the same grain mixture, one of them having part of the grain replaced by sprouted fodder.

There were 6 calves in each group. All were started on whole milk, 1 lb. per 10 lb. liveweight. Whole milk was continued at this level, up to a maximum of 15 lb. per head for group 1 throughout the experiment. The change for the other groups to reconstituted skimmed milk (1 lb. dried skimmed milk to 9 lb. water) was gradual, beginning at about 30 days of age. A maximum of 1·5 lb. skimmed milk powder per head daily was allowed.

At 3 weeks of age hay, which was fed to appetite, and the grain mixture were introduced. The grain mixture consisted of (in parts) maize 4, oats 3, bran 3, linseed cake 1, decorticated earth nut cake 0·5, and herring meal 0·5. The allowance was $\frac{1}{4}$ lb. per head daily during the 4th and 5th weeks and it was increased by $\frac{1}{4}$ lb. each week thereafter. In addition the absence of butter fat from the skimmed milk was compensated for by feeding $\frac{3}{4}$ lb. flaked maize for each 1 lb. skimmed milk powder.

During the first period, to about 1 month of age, no sprouted maize was fed. In the second period, group 3 received at first 1 oz. of sprouted maize per head daily, replacing an equivalent amount of dry matter of flaked maize, and the ration was gradually increased to $\frac{1}{4}$ lb. at the end of the second month and to $1\frac{1}{2}$ lb. at the end of the third month. The results are shown on p. 26.

The sprout-fed calves did well in the second month but not in the third, when the amount of sprout was increased.* Sprout at the higher levels had a diuretic effect.

* Principal Paterson, of the West of Scotland Agricultural College, is of the opinion (private communication) that there would have been a difference in liveweight gain in favour of sprout fodder had the amount fed not been increased. He also considers that the fattening experiment F (*see* table, p. 22) indicates that the best effect is got by feeding only small amounts.

Live Weight Gains.

Period.	1.		2.		3.	
	Lb.	Per cent.	Lb.	Per cent.	Lb.	Per cent.
Group 1 : whole milk, hay and grain . .	33·0	41	49·5	102	66·1	183
Group 2 : skimmed milk powder, hay and grain	32·6	37	46·7	90	51·8	149
Group 3 : skimmed milk powder, hay, grain, and sprouted maize .	27·0	32	49·6	90	51·5	150

A further trial was made on 9 calves, carried on for 30 days after conclusion of the main experiment. They were divided into 3 groups and each fed 1½ lb. dry skimmed milk, 2-3 lb. hay, and increasing amounts of the same grain mixture as above. The first group had flaked maize in the same proportion to skimmed milk powder as before ; the second had part of the flaked maize replaced by ¾ to 1 lb. per head daily of sprouted maize and the third had twice that allowance of sprouted maize.

The average total and daily live weight gains for the three groups were, in lb. : 59·7, 53·6, and 51·0 ; 1·99, 1·79, and 1·70.

Hence sprouted maize was inferior to flaked maize for growth of calves and growth was less with the higher than with the lower allowances of sprout.

Pigs.

Experiments with fattening pigs are reported from three centres, Wye, Berlin, and Hawkesbury College, N.S.W.

Wye.

A feeding trial (19) was begun in September, 1937, with 2 groups, each of 3 paired lots (size not given) of pigs. The ration fed was, in percentages : barley meal, 30 ; flaked maize, 15 ; weatings, 45 ; fish meal, 7·5 ; soyabean meal, 2·5. After a weight of 100 lb. had been reached, the composition was changed as follows : barley meal, 40; flaked maize, 20 ; weatings, 25 ; bran, 5 ; soyabean meal, 10. Chalk, 1·5 lb., and salt 0·5 lb. per 100 lb. meals were added.

Sprouted barley was fed as an addition to this ration, 2 lb. per lot daily, to one of each paired lot.

The experiment was concluded in December because difficulty with temperature regulation (lack of insulation) made the growth period too long for practical purposes. The results showed excess weight gains for the 3 sprout-fed lots of 21, 23, and 28 lb. ; the amounts of sprouted barley going to produce 1 lb. surplus weight were calculated to be 8·00, 7·22 and 7·78 lb. The conclusion is, therefore, that there is no evidence that sprouted barley had any "accessory" food value when fed as a supplement to a normal meal ration.

A preliminary trial is also reported of the value of sprouted barley for weaning pigs. Six pairs of sows and litters were used. The piglings ate the sprouted barley but not earlier than they ate meals, and there was no evidence that the sprouted barley had any special value for the young pigs.

Berlin.

The first experiment (Koppehof Station) (38) was on 3 groups, each of 8 pigs. The basal diet for all was steamed or ensiled potatoes *ad lib.* The control group had a protein supplement of 700 g. crushed barley and 200 g. fishmeal per head daily. One experimental group had, at the suggestion of the representative of the firm supplying the sprout apparatus and nutrient solution, a supplement only of 1·5 kg. sprout fodder per head daily. The second experimental group were given 350 g. crushed barley, sprout fodder from 350 g. barley, and 200 g. fishmeal.

The results were as follows :—

	Control.	Sprout 1·5 kg.	Sprout from 350 g. Barley (about 1·4 kg.).
No. in group	8	8	8
Av. initial wt., kg.	27	27	27
Av. final wt., kg.	103·7	79·3	103·0
Av. gain, kg.	76·7	52·3	76·0
Av. feeding time, days	79	79	79
Av. daily gain, g.	644	437	639
,, ,, lb.	1·42	0·96	1·41
Dig. prot. per kg. gain, g.	407	324	415
Starch equiv. per kg. gain, g.	2280	3177	2130

It is clear that with a basal ration of steamed potatoes *ad lib.* the supplement of 1·5 kg. sprouted fodder was quite inadequate to replace

the usual concentrate supplement. Growth was retarded and, although protein consumption per kg. liveweight increase was less than in the other groups, energy consumption was nearly 50 per cent. higher. The group with part of the concentrate supplement as sprouted fodder used 2 per cent. more protein and 7 per cent. less energy per kg. gain in weight, differences which are not considered significant.

Two tests were then made at the Dahlem Station (41). In one there were three groups, each of 6 pigs. The basal ration was a cereal and protein mixture fed to appetite. At first the protein, fishmeal, constituted 16 per cent. and later 8 and 4 per cent. of the mixture. A second group had 300 g. barley replaced by 1175 g. sprout fodder, and a third was fed like the second to a weight of 35 kg. and thereafter had the sprout fodder as sole protein supplement.

In this experiment a different cabinet was used with internal lighting, giving green fodder.

The results are summarised thus :—

	Controls.	Sprout 1.	Sprout 2.
No. in group	6	6	6
Av. initial wt., kg. . . .	26·2	24·3	23·7
Av. final wt., kg. . . .	103·8	103·5	98·3
Av. gain, kg.	77·6	79·2	74·6
Feeding time, days . . .	147	154	161
Av. daily gain, g. . . .	528·0	514·0	463·0
,, ,, lb. . . .	1·16	1·13	1·02

No information is given as to food consumption per kg. liveweight increase.

In the second test barley alone was fed, one group receiving the

	Control.	Sprout.
No. in group	5	5
Av. initial wt., kg. . . .	47·0	47·0
Av. final wt., kg. . . .	108·4	107·8
Av. gain, kg.	61·4	60·8
Feeding time, days . . .	133	133
Av. daily gain, g. . . .	462·0	457·0
,, ,, lb. . . .	1·02	1·01
Dig. prot. per kg. gain, g. . .	433	424
Starch equiv. per kg. gain, g. .	4002	3845

equivalent of 300 g. barley as sprouted fodder. It was thought that, if at all, the special properties of sprout must become evident under these conditions.

No advantage is evident in rate of gain in weight, nor any significant advantage in food utilisation (advantage for sprout, 2 per cent. in protein and 4 per cent. in energy used for 1 kg. gain in weight).

A second experiment at Koppehof is also reported in which steamed potatoes were fed as basal diet ; one group had as supplement 450 g. crushed barley and the other 1·5 kg. sprout fodder.

	Control.	Sprout.
No. in group	8	8
Av. initial wt., kg. . . .	28	28
Av. final wt., kg. . . .	72·8	57·0
Av. gain, kg.	44·8	29·0
Feeding time, days (calculated) .	120	120
Av. daily gain, g. . . .	373	243
,, ,, lb. . . .	0·82	0·53
Dig. prot. per kg. gain, g. . .	358	539
Starch equiv. per kg. gain, g. .	3571	5130

Addition of 200 g. fishmeal daily to both rations gave increases in rate of liveweight gain to 731 g. per day for the controls and 674 g. for the sprout fed. Digestible protein and starch equivalent used per kg. increase in weight were still higher for the sprout fed, 399 g. and 2724 g. as against 363 g. and 2533 g.

These experiments therefore give uniform negative results as regards rate of gain in weight. Examination of the carcases from the Dahlem experiments also showed no difference in conformation or quality of flesh or fat.

Hawkesbury Agricultural College, N.S.W.

A test is reported (10) on 4 groups, each of 6 pigs. Groups 1 and 2 had a basal ration of boiled wheat, 6·2 lb. ; separated milk, 4·25 lb., and pollard, 0·5 lb. daily. Group 1 had, in addition, 2 lb. green feed (green barley and lucerne) and group 2, 2 lb. sprouted maize. The basal ration for groups 3 and 4 was 2·14 lb. dry wheat and 6 lb. separated milk ; the supplements were again 2 lb. green feed or 2 lb. sprouted maize.

Only half of the sprouted maize fed was eaten, and in Group 4 about 40 per cent. of the dry wheat was rejected also.

The results are definitely in favour of natural green fodder :—

	1. Green Feed.	2. Sprouted Maize.	3. Green Feed.	4. Sprouted Maize.
No. in group	6	6	6	6
Av. initial wt., lb.	59·5	57·8	53·6	50·1
Av. final wt., lb.	79·3	75·1	75·3	64·6
Av. gain, lb.	19·8	17·3	21·7	14·5
Feeding time, days	28	28	28	28
Av. daily gain, lb.	0·71	0·62	0·78	0·52

It is reported that when fodder from wheat, rye, barley, field peas, Japanese millet and maize was later fed to pens of pigs, the preference was for wheat and rye, followed by barley. The others were eaten only after these were finished.

Experiments with pigs, therefore, show no evidence of any special properties of sprouted fodder.

THE EFFECT OF GERMINATED GRAIN ON REPRODUCTION IN FARM ANIMALS.

The studies to be discussed below have not been made with fodder produced by any of the commercial methods but with oats soaked in water and grown in trays in " an ordinary sprouter " or in tubs, at a temperature of 75°-80° F. (23·9°-26·7° C.). Growth for 5 to 8 days has been usual.

Following the discovery by Evans and his colleagues (18) of the presence *in green food* of a substance necessary for successful gestation in the rat, and named vitamin E, it was thought that the rations of cows stall-fed on dry rations might be deficient in this vitamin and that the deficiency might be the cause of infertility (24, 26, 29). It is difficult to understand why sprouted oats should have been chosen to be tried as a corrective, but extensive trials have been made, using daily supplements of the crop from 2·5-5 lb. of dry seed. The procedure has usually been to select heifers and cows which, after a number of services, have failed to conceive (as judged by reappearance of oestrus), and to feed sprouted oats. If the number of services from

the commencement of this treatment to conception is less than the number preceding treatment, the sprouted fodder is held to have been beneficial. Beneficial results are commonly claimed, except in cases of cystic ovaries.

Leaving, for the moment, the question of whether or not the treatment is based on reasonable assumptions, this method of experimentation and of interpretation of results is open to criticism. A certain number of unsuccessful services must occur before the cow is selected for treatment, as suffering from "temporary sterility"; obvious pathological conditions must not be present. The following are illustrative examples of case histories (24). A cow which was served 4 times before feeding sprouted oats and 3 times after, and a heifer which was served 5 times before sprouted oats and once after, were held to be benefited by the treatment. On the other hand, animals served 4 or more times per conception while being fed sprouted oats were held not to have benefited. There is obviously no basis on which to judge whether they would, or would not, have conceived at the same service without sprouted oats. A statistical analysis of the number of services per conception in cows which *had already had* 3, 4, 5 or more services would be required for an adequate number of cows (possibly 100 at least) to provide a satisfactory basis on which to judge the effect of any treatment. No such analysis has been found.*

Observations in which more confidence can be placed, since parallel records are available for control, untreated, groups have been made at the Hawaii and University of Nebraska Agricultural Experiment Stations.

In the former (26) 75 cows were selected as "shy breeders" and allocated alternately to two groups. One was fed daily sprouted oats from 2 lb. dry seed, as a supplement to a diet which already provided abundant green food. A group of 28 sows, similarly selected, was divided into sub-groups of which one was also treated with sprouted oats equivalent to 1 lb. of dry seed daily.

* The same criticism applies to recent experiments in which injection of wheat germ oil has been followed by conception and in which, therefore, vitamin E is held to have "cured" sterility. Bacharach (5) points out the same fallacy in observations on the treatment, with wheat germ oil, of habitual abortion in women. "There do not appear to be available any statistics showing the number of full-term births that would be expected in a group of, say, 100 untreated women who had had two or more successive miscarriages."

Selection from the data presented of histories including services both before and after sprout feeding, gives the following results :—

Nine cows which had not come in heat 4 months after calving were fed sprouted oats. The average number of services per conception was 2·2. Nine similar controls required 2·0 services per conception.

Seventeen cows and heifers, which had been bred but had come in heat again, were fed sprouted oats. Of these, 11 produced calves with an average of 2·45 services before and 1·73 after sprout feeding ; total 4·18. The remaining 6 produced no calves after 2·5 services before and 6·2 after sprout feeding ; total 8·7. The controls numbered 25, and of them 18 produced calves for an average of 4·17 services, and 7, averaging 4 services, produced no calves. These records show no advantage from sprout feeding.

The sow records are similar. Nine were sprout fed and produced 7 litters with an average of 2·14 services before sprout feeding and 2 after ; total 4·14. Of the two that had no litters, one was served 3 times before and 4 times after sprout feeding ; the other was served 5 times before but not served at all after sprout feeding.

Among the 13 controls, 9 had litters with an average of 3·44 services and 4 had no litter after an average of 3·25 services.

Again no advantage for sprout feeding is shown.

In the second series (14) mass observations were made of the breeding efficiency of the whole herd, to which about 6 lb. sprouted oats per head was fed daily between the years 1926 and 1931. Results during this period were substantially the same as during the preceding and following 5-year periods.

In addition, controlled experiments were made with groups of 10-12 heifers in each of the years 1931, 1932, and 1934. In the first year both groups were given alfalfa hay *ad lib.* ; the test group 4 lb. sprouted oats per head daily. In 1932 one group received, in addition to a basal ration of alfalfa hay and silage, 2 lb. dry whole oats, the other 4 lb. sprouted oats. In 1934 alfalfa hay was again the basal ration and one group was given 4 lb. dry oats, the other 4 lb. sprouted oats. There was no significant difference in any year. The average number of services per conception in the sprout-fed heifers, taken together, was 2·7 and in the controls 2·8.

These results, therefore, both for the general herd and for controlled experiments, agree with the Hawaiian in showing no benefit from feeding germinated oats.

Since these tests have been confined to one specific food, germinated

oats, it may be worth while to examine the underlying assumptions on which the work is based. These are (*a*) that practical dairy rations may be deficient in vitamin E and (*b*) that germinated oats are a rich source of vitamin E.

To justify or dispose of the former assumption information is required on both the vitamin E content of dairy rations and the vitamin E requirement of dairy animals.

It can be said with certainty that wheat germ (and wheat germ oil), rice oil (from rice polishings), cotton seed oil, palm oil, and certain green leaves contain vitamin E in considerable amounts (5). According to the early studies of Evans and Burr (18), corn germ and alfalfa are excellent sources and cocoanut press cake is also a good source of the vitamin. Oils from barley and oat seed (germ was not separately tested) were relatively poor, but not devoid of the vitamin.

Hathaway and Davis (25), using the curative rat test, assayed a number of the foods commonly used in dairy rations (bran, shorts, linseed oil meal, hominy feed, white and yellow corn, cottonseed meal, kafir, alfalfa, corn gluten and beet pulp) and found that all except corn gluten and beet pulp supplied adequate amounts of vitamin E when constituting 20 per cent. of the rat's food. They rank possibly at about the same value as cocoanut press cake in Evans and Burr's experiments.

Since, therefore, dairy rations usually contain whole cereal, wheat or corn, which includes the germ known to be rich in vitamin E, and milling offal with green food, it seems unlikely that they would ever be deficient as judged by rat tests.

On the other hand, there is no evidence to show that germinated oats are, in fact, a rich source of vitamin E. Evans and Burr did not find the oil of oat seed to be so.

Nor is there any evidence to show that rations low in vitamin E would produce in farm animals results similar to those of vitamin E deficiency in rats. The characteristic effects in rats are interruption of gestation with resorption of the foetus, and Bacharach (6) considers that, after resorption gestations, there may be an increasing tendency to failure of implantation. Only one experiment with farm animals has been made with a ration known to be practically free from vitamin E. Wilson, Thomas and Cannon (55) fed 6 female goats on a ration of alfalfa hay and grain, treated with a solution of ferric chloride and ether to destroy vitamin E. This was supplemented with cod liver oil and yeast, both shown, by tests on rats, to be free from

vitamin E. Each batch of the ration made up was tested on rats. In the first year of the experiment, 5 of the 6 goats produced a total of 9 kids, 8 alive and 1 dead-born ; 5 males and 3 females. These males, themselves born and reared on the deficient diet, were used for breeding and, in the second year, the 6 original females produced 9 kids, 5 male and 4 female, all strong and healthy. Of the 3 first generation females, 1 showed poor growth. The other 2 were bred and produced 4 kids, 3 male and 1 female, all also strong and healthy. All the second year kids were sired by the males on deficient diet.

These results show that vitamin E deficiency, for 2 years and through 2 breeding seasons, has no effect on adult goats, and no effect on the breeding efficiency in the first season of either males or females born and reared on deficient diet.

There is, therefore, no reliable evidence that the feeding of germinated oats has any effect on the breeding efficiency of cows or sows.

The feeding of germinated oats, with a view to improving breeding efficiency, appears to be based on erroneous assumptions since

(1) there is no evidence that practical dairy rations are deficient in vitamin E as judged by rat tests ;

(2) there is no evidence that germinated oats are a rich source of this vitamin ;

(3) there is no evidence to show whether or in what way farm breeding stock in general react to a deficiency of vitamin E. One experiment with goats, covering two generations on a diet free from vitamin E, showed no evidence of harmful effects.

Recent work has shown that hens fed abnormal rations restricted to foodstuffs known to contain little or no vitamin E (7, 16), give eggs of low fertility and hatchability. Embryo mortality during the first 4 days of incubation is greatly increased. Addition of wheat germ or wheat germ oil to such rations improves fertility and hatchability definitely but not to the level of a normal ration.

It would appear, therefore, that hens do require vitamin E, but that normal rations provide adequate supplies.

From the poultry experiments described below, it will be shown that sprouted grain, oats in three cases, and equal parts of wheat and oats in one, had a favourable effect on hatchability of eggs. From what has been said above regarding the vitamin E content of oats and the composition of the basal rations used, it seems unlikely that any part of the effect should be due to vitamin E.

THE EFFECT OF GERMINATED GRAIN AND SPROUT FODDER ON POULTRY.

Before the commercial exploitation of sprouted fodder, there are many reports on the feeding of germinated cereals to poultry. Some of these are reviewed by Smith (44) and McCandlish (31). Detailed results are not always presented but only general findings, some positive and some negative (45, 49).

Egg Production and Hatchability.

Mangold, in his handbook of the nutrition and metabolism of farm animals (30) recommends the feeding of germinated cereals for egg production, on the basis of two practical tests quoted and an experiment made for him. He says that microscopic examination of the excreta showed much better digestion of the bran. The seedlings used were four-day-old wheat.

Thomas (47) reports on experiments made in 1926 in Victoria (N.S.W.) on the use of germinated oats and lucerne chaff as substitutes for green feed in the rations of laying birds. A study of the variability of egg production indicated that pens of 50 birds and an experimental period of about a year would be necessary to show real differences in value.

Four groups, each of 50 white Leghorn pullets, equalised as to ancestry, were given a basal ration of bran 30, pollard 60, and meat meal 10 per cent. The grain mixture was of wheat 57, barley 29, and yellow maize 14 per cent. from May to July, and of wheat 75 and barley 25 per cent. from August to March. The first group was given a liberal allowance of lucerne or green barley ; the second no green food ; the third 27 g. per head (3 lb. per pen) of germinated oats daily ; and the fourth a similar amount of lucerne chaff steeped in water for 24 hours.

For the experimental period of 316 days, mean egg yields per bird were : Group 1, 167·5 ; Group 2, 139·2 ; Group 3, 136·7, and Group 4, 151·2. Egg weights were not recorded. Sprouted oats were therefore inferior for egg production to a ration of grain and meat meal alone, and still more inferior to the same ration with green food.

The egg yolks in groups 2 and 3, after 70 days on experiment, showed lack of pigment, the sprouted oats group being most affected.

Five months after yellow maize was omitted from the ration, the

birds in group 2 developed symptoms of vitamin A deficiency, and many deaths occurred. Birds on sprouted oats were unaffected. Sprouted oats must therefore contain sufficient carotene when fed at this level in addition to the basal ration to prevent obvious symptoms of deficiency. This is in agreement, Thomas says, with the results of Davis and Beach (1925) who showed that sprouted oats equivalent to 20 per cent. of the ration maintained birds in health.

There was no significant difference in bodyweight of the birds at the end of the test.

Westermarck (54) reports that oats germinated for 8 days (comparable with sprout fodder) had a favourable effect on egg size and therefore on total egg weight. In an experiment on 2 groups, each of 10 laying hens, one of which received germinated and the other ungerminated oats, fertility and hatchability of eggs were compared during a period of 30 days, followed by an interval of 9 days and a second experimental period of 30 days in which the experimental oat rations were reversed. The average results for the two periods were as follows :—

Fertility :

with ungerminated oats,	61·1 per cent. ;
with germinated oats,	77·25 per cent.

Eggs hatched as percentage of the fertile :

with ungerminated oats,	98·1 per cent. ;
with germinated oats,	72·0 per cent.

There was thus a net advantage of over 4 per cent. eggs hatched in favour of ungerminated oats.

Smith (44) describes tests extending over 4 years on the effect of various supplements to a basal ration of grains, meat scrap and buttermilk with oyster shell grit. In the first test, December, 1927, to June, 1928, the birds were confined throughout. In the second, November, 1928, to September, 1929, and third, November, 1929, to August, 1930, they had access to outdoor gravel pens with a limited amount of green food.

Pens of 20-24 white Leghorn pullets were used. The supplements compared were : mineral, bone meal 4, and salt 1 per cent. of the mash ; cod liver oil, 2 per cent. of the mash ; germinated oats, 2 lb. dry weight daily to 100 pullets ; alfalfa leaf meal, 10 per cent. of the mash ; various combinations of these.

Only the first three tests are of interest here because in the fourth germinated oats were fed only in combination with other supplements.

From the data presented the following, which show definite differences, are selected :—

	Hen Days.	Production (1).	Hatchability (2).	Fertility (3).	Average wt. of Eggs : g.
Test 1 : Confined					
No supplement .	3144	35·7	50·0	67·2	53·8
Mineral . .	2728	36·3	49·3	93·1	53·3
Cod liver oil .	2659	35·4	52·7	76·7	52·7
Alfalfa leaf meal .	2395	35·4	55·9	89·1	54·1
Germinated oats .	2893	38·0	65·9	87·6	56·4
Test 2 : Sun + limited green feed					
No supplement .	5862	47·5	66·3	93·3	52·2
Mineral . .	6105	47·8	72·5	93·3	52·4
Cod liver oil .	5437	50·2	69·6	78·0	52·4
Alfalfa leaf meal .	6102	38·9	70·1	92·3	52·2
Germinated oats .	6320	46·5	59·8	92·3	54·1
Test 3 : Sun + limited green feed					
No supplement .	4523	43·9	86·1	93·3	55·3
Mineral . .	4786	34·4	73·4	97·2	56·4
Cod liver oil .	4148	46·2	76·1	93·5	54·1
Alfalfa leaf meal .	4516	44·5	85·9	91·1	53·6
Germinated oats .	4485	49·2	79·2	93·1	53·8

(1) Total no. of eggs divided by no. of hen days.
(2) Percentage of fertile eggs hatched.
(3) Percentage of eggs set that are fertile.

It will be seen that, as a supplement to a normal ration, when the hens are confined, germinated oats gave the best results for production, hatchability and average weight of eggs, with a definite improvement over the basal ration for fertility. But when added to the same ration when the hens were in the open with limited green feed, there was only a slight superiority of egg weight in one test and egg number in the other. Germinated oats were inferior to the basal ration for both hatchability and fertility in both tests.

Weinmiller and Voigt (53) report a test on 6 comparable groups each of 20 white Leghorn pullets. In addition to a mash of " clubkraft," ground cereals and potato flakes, two groups received as grain ration wheat, two oats, and two oats germinated for 4 days. The

last group gave the best results, followed by wheat. Egg yield (weight) in the group on ungerminated oats was only 85 per cent. of that on germinated oats.

Weinmiller and Mantel (52) describe a further experiment with rye, barley and soya bean, germinated for 2 days only, so that the embryo had just broken the seed coat. Six groups, each of 27 hens, were used and the period of test was 3 months. The basal ration was of 25 parts rye, 35 parts wheat, 15 parts oats (all crushed) and 25 parts "clubkraft." All received daily 15 g. of this mixture with 1 g. cod liver oil, and 50 g. whole wheat. The mixture was further fed dry to appetite and milk and water were provided to drink. Two groups received each at first 10 g. germinated soya bean, rye or barley; the quantity was reduced to 7 g. during the last month because the 10 g. were not completely eaten.

Egg production ("standard eggs" of 55 g. weight) over the experimental period was: on germinated soya bean, 44·57; on germinated barley, 43·03; and on germinated rye, 41·27 per head.

Lang (27) presents the results of a nine months' experiment with white Leghorn hens of different ages. There were 7 groups of about 114 hens in each and an eighth group with 224 hens. The basal ration consisted (in percentages) of potato flakes, 20; dried beet slices, 15; wheat bran, 20; crushed oats, 10; herring meal, 5; bone meal, 5; meat and bone meal, 10; soya bean meal, 10; cod liver oil, 1; mineral mixture (Lehmann), 2, and calcium carbonate, 2. This mixture was fed to appetite and a grain ration of wheat, barley and maize; wheat, barley and oats, or wheat and barley was given.

All groups had skimmed milk, the consumption of which averaged about 47 g. per head daily. Group 1 had about 150 g. milk. Group 2 consumed about 18 g. cabbage and 22 g. greens; group 3 about 21 g. carrots and 21 g. greens. All groups received some germinated oats, averaging about 5·5-6 g. per head daily; group 4 consumed daily about 22 g. Group 5 consumed on an average 17·5 g. silage and 23 g. greens; group 6, 3·3 g. lucerne hay; group 7, 22 g. mangolds and 19 g. greens, and group 8 about 21 g. of a mixed supplement, and 20 g. greens.

The results of the hatching season are shown on the opposite page.

It will be seen that Group 4 with germinated oats as special supplement (22 g. per head daily) gave the best results for hatchability, both as a percentage of eggs set and of eggs fertile.

Group.	Eggs Set.	Infertile per cent.	Hatched per cent. of Set.	Hatched per cent. of Fertile.
1	2217	16·7	65·9	79·5
2	2089	8·6	73·5	80·4
3	1836	6·3	69·7	74·3
4	2051	7·7	74·7	81·0
5	1918	13·1	68·5	78·8
6	1560	7·5	71·5	77·3
7	1804	11·4	67·0	75·6
8	3097	9·8	70·6	78·2

Perhaps the most important data on the effect of sprouted grain on hatchability of eggs are to be found in Axelsson's (2, 3) studies of porosity of shell in relation to hatchability. It appears from his reports that the use of sprouted grain in rations during the hatching season is (or was) fairly common practice in Sweden, but he says that opinion was much divided as to its effects. In his studies he showed that hatchability of eggs is correlated inversely with porosity of shell, as measured by loss of weight (evaporation) under standard conditions of temperature (20° to 24° C.) and humidity (50-70 per cent.). Porosity is low and hatchability high during the summer months. Hatchability begins to decrease in autumn and decreases progressively during confinement on winter rations. It may be at its lowest level during the usual hatching season.

Hatchability of Eggs Grouped According to Weight Loss. Spring, 1930. Percentage.

Weight Loss g.	All Home Produced Eggs.	Bought Eggs.
0·061—0·080	64·00 ± 9·60	100·00 ± 0·00
0·081—0·100	68·39 ± 3·52	66·67 ± 15·7
0·101—0·120	67·61 ± 1·91	52·63 ± 11·5
0·121—0·140	66·73 ± 2·02	30·56 ± 7·7
0·141—0·160	65·90 ± 2·54	47·37 ± 11·5
0·161—0·180	55·71 ± 4·20	18·18 ± 11·6
0·181—0·200	48·08 ± 6·93	11·11 ± 10·5
0·201—0·220	22·22 ± 9·80	0·0
0·221—0·240	0·0	0·0
Average .	64·22 ± 1·10	30·08 ± 3·88

Experiments were made to test the effect of sprouted grain by adding it in February when the shell would usually show a fairly high porosity. The basal ration consisted of a dry mash of the following percentage composition : wheat bran, 40 ; maize meal, 10 ; mixed crushed grains, 10 ; soya bean meal, 10 ; linseed meal, 5 ; lucerne hay meal, 10 ; meat and bone meal, 10, and fishmeal 5. To each 100 kg. of this mixture were added 3 kg. yeast, 1 kg. cod liver oil, 0·5 kg. charcoal and $\frac{1}{3}$ kg. salt. This mash and oyster shell grit were fed to appetite. In addition 50-60 g. whole grain per head and 5 kg. buttermilk per 100 birds were allowed daily.

Addition to this ration of 4 g. per head daily of chalk had no effect on porosity of shell.

In the sprouted grain experiments, 10 g. daily replaced 5 g. dry grain. Equal parts of wheat and oat were used as seed and the seedlings were allowed to grow for 5 days at a temperature of 30° C. in a lighted cabinet.

Comparing the porosity of shell of eggs from 8 hens which had laid continuously 39 eggs before and 39 eggs after feeding sprouted fodder, average losses of weight during the first 24 hours after laying of 203 mg. (before) and 154 mg. (after) were found. The reduction of 49 mg. is significant.

In addition, comparison was made (by race) between the general results during the period 6th November to 13th February before feeding sprouted grain and 14th February to 18th April with sprouted grain.

	White Leghorn.	Rhode Island Red.	Barnevelder.
Before—			
No. eggs	324	110	143
Av. loss of wt., mg. . .	184	272	208
After—			
No. eggs	269	311	140
Av. loss of wt., mg. . .	131	147	145
Difference in favour of sprouted grain : mg. . . .	53	125	63

The whole of the difference in these massed results cannot, however, be attributed to sprouted grain, because most of the hens had a " resting period " during the early part of the year. It is shown that such an interval, when egg laying stops, both in hens fed and those not fed sprouted grain, causes a reduction of porosity, shown in both cases by a reduction in loss of weight of 16-37 mg. Allowance for this still leaves a significant difference in favour of sprouted grain, highly significant in the case of the Rhode Island Reds.

From estimations of the calcium content of the shell of two eggs, one of relatively low, and the other of very high porosity, Axelsson attributes the high porosity to imperfect calcification (inorganic matter in the former 95·8 per cent. ; in the latter 91·6 per cent. by weight). In later experiments he found that feeding vigantol during a season of high porosity and low hatchability gave a very definite improvement.

Discussing possible reasons for the beneficial effect of sprouted grain he says : " It is conceivable that sprouted grain, because of its richness in vitamins and its higher content of enzymes, might influence calcium metabolism in the animal body in a favourable manner, so that a better shell might result from feeding it."

He does not, however, offer any proof that the calcium content of shell is the only factor controlling porosity and, while it seems likely that the effect of vigantol is due to increase in the calcium content of shell, the effect of sprouted grain might conceivably be of quite another kind.

In this connection it is of interest to note that it has recently been shown (15) that the vitamin B_2 complex or some constituent of it is necessary for successful reproduction in poultry, a deficiency resulting in increases of both the usual peaks (3rd and 7th to 10th days) of embryonic mortality and a hatchability of less than 10 per cent. These results, however, arise from the use of a ration of grain (maize and wheat), bran, purified casein and lactalbumin, with the usual supplements of cod liver oil, calcium and salt. Addition to this ration of riboflavin greatly improved hatchability. It is difficult to imagine that a deficiency of B_2 complex could be operative in Axelsson's experiments where the ration contained lucerne meal * and yeast and 50 ml. buttermilk per head were allowed daily. From the estimate of the riboflavin content of sprouted oats (maximum 0·06 mg. per 100 g.

* Riboflavin content in mg. per 100 g. (20) : lucerne meal, 0·7 ; yeast, 1·8 to 3·6 ; milk (per 100 ml.), 0·1 to 0·3.

dry matter) (17) the increase in total riboflavin content of the ration from feeding 10 g. germinated oats daily would appear to be insignificant. We have no information about the other constituents of this complex.

Growth.

One report (23) has been published in which extraordinary results in growth are claimed for cabinet culture fodder. Three groups of 50 day-old chicks were placed in brooders and fed as follows: (*a*) 49 lb. minced sprouted maize, with the moisture saved, mixed with 32 lb. middlings, 16 lb. bran, $3\frac{3}{4}$ lb. fishmeal, 5 lb. buttermilk, $1\frac{1}{4}$ lb. soyabean meal, 3 lb. oyster shell grit, 1 lb. charcoal and 1 lb. salt; (*b*) 49 lb. minced sprouted wheat, 48 lb. maize meal, $3\frac{3}{4}$ lb. fishmeal, and the other ingredients as above; (*c*) "ordinary chicken feed." The rations were fed in troughs to appetite. The report on growth is quoted verbatim.

"Of the three batches of chickens the sprouted maize fed one raced ahead. They did not weigh any heavier the first three weeks, but at eight weeks the average chick in this group weighed 2 lb., leaving their contemporaries well behind.

"At the tenth week the maize was discontinued so that the flesh of the table chickens should not be tinted, and more milk, etc., was substituted. By twelve weeks many weighed 4 lb., the average over $3\frac{1}{2}$ lb. When they came to table the flesh was firm and white and the flavour excellent."

No information is given as to the breed used in these experiments, but, in view of the fact that the average weight of light breeds, in records covering thousands of birds, is only 1 lb. to 1·5 lb. at 8 weeks and 2 lb. to 2·4 lb. at 12 weeks, and that even heavy breeds take 11 weeks to reach a weight of 2 lb. and 18 weeks to reach a weight of 4 lb., this ration appears to be worth testing on a larger scale.

SUMMARY OF FEEDING EXPERIMENTS.

From three centres controlled experiments on dairy cows are reported. These show no special advantage in sprouted fodder for milk production, but indicate that it may replace an equivalent amount of silage or kale in short period trials (1 to 3 months).

Tests on beef cattle in which sprouted barley replaced the equivalent weight of seed in the concentrate ration showed no improvement

in rate or economy of liveweight gain. Trials on a much larger scale at one centre in which sprouted maize replaced an equivalent (dry matter) amount of swedes, showed highly significant increases in rate of liveweight gain, and gave excellent quality of beef.

A single experiment with calves showed that sprouted maize was of less value for growth than flaked maize and that growth was less on a higher than on a lower allowance of sprout.

Three centres report negative results with pigs.

Observations on the effect of feeding germinated oats to cows and sows suffering from " temporary sterility " are discussed. Controlled experiments show no benefit from this treatment, either in number of animals conceiving during the term of the experiments or in the number of services per conception.

Experiments with laying hens show a balance of evidence that germinated grain or seedlings of a few days' growth, added to rations without green food or with hay meal in winter and spring, improves egg yield, fertility and hatchability. When the ration contains fresh green food no benefit is found from feeding germinated grain.

SHORT NOTE ON SPROUTS IN HUMAN DIET.

No trials appear to have been made of sprouts prepared by large scale processes in human diet. The use of sprouts in human diet is, however, well known and of ancient date. Mustard and cress seedlings as trimmings for sandwiches and in salads are familiar in this country. In the Philippine Islands and Hawaii (12) legume sprouts (6 to 9 days) are commonly prepared by germination on rice straw. The seed coat is shed or removed at this stage and the seedlings are eaten raw or cooked. In Malaya legume seedlings are an important native vegetable sold in the markets. They are also used in India, but to what extent is not known. The use of sprouted legumes for scurvy prevention is well known and the preparation of cereal and legume seedlings is recommended for this purpose in Aykroyd's Bulletin on " The Nutritive Value of Indian Foods and the Planning of Satisfactory Diets " (4).

COST OF PRODUCTION.

The proprietors estimate the cost of production of sprouted fodder as follows :—

Cabinet Culture.—The standard cabinet costs £122 10s.

Weekly Cost of Running the Standard Cabinet.

	£	s.	d.	
Depreciation at 10 per cent. per annum	0	4	0	
Labour, ¾ hour per day at 9d.	0	4	0	
Seed (maize) 3 cwt. (48 lb. per day) at 6s.	0	18	0	
Heating (fuel for burner)	0	2	6	
Nutrient salts, 6d. per day	0	3	6	
Total weekly cost	1	12	0	
The Standard Cabinet produces 14 cwt. of fodder per week at a cost of £1 12s. which is approximately	2	5	0	per ton.

Sprout Process.

Interest (depreciation) on capital outlay of £125 unit at 20 per cent. per annum (5 years)	0	9	7
Labour, 2½ hours daily at a weekly wage of 30s. for 56 hour week	0	9	4
Maize (average price per annum £5 15s. per ton), ¼ ton	1	8	9
Sprout nutrient	1	0	0
Fuel, coke 1¼ cwt. (average market price 30s. per ton)	0	1	11
Weekly average	3	9	7

This is also the cost per ton.

These figures would have to be adjusted for differences in cost of labour and seed in different countries. For the United Kingdom they might be criticised on three scores, namely, the allowance for labour, the cost of seed and the weight of crop relative to seed.

The yield of sprouted maize at Reading, with a ten-day rotation, was not more than 3·5 and at Hawkesbury College 3·8 times the seed weight. At Auchincruive (digestibility trials) it was only 3·22. A ratio of 3·5 might therefore be taken as a possible average and the yield from 3 cwt. of seed would then be 10·5 cwt. in 10 days.

The present cost of maize seed in this country is about 7s. 6d. per cwt., and of labour about 1s. per hour.

If the estimates are revised to allow for these higher costs of seed and labour and for a yield of only 10·5 cwt. of fodder from 3 cwt. of seed, the cost per ton becomes 72s. for Cabinet Culture and 99s. for Sprout Process fodder. The difference between these estimates is due chiefly to the higher allowance for labour, 2½ hours daily, by Sprout Process than by Cabinet Culture, ¾ hour daily; and the higher cost, per ton of fodder, of Sprout Process nutrient.

The estimate from Hawkesbury College is much higher, namely, per ton of fodder :

	£	s.	d.
Electricity at 3d. per unit	4	13	6
Seed at 5s. per bushel, 15·36 bushels . .	3	16	9
Labour, 20·48 hours at 1s. 5d. . . .	1	9	1
Cost (without nutrient solution, interest and depreciation)	9	19	4
Or adding cost of solution and depreciation per ton from above Cabinet Culture estimate .	0	14	3
Cost per ton	10	13	7

No estimate of total cost was made at Reading, but on the assumption that 2 lb. maize fodder is the equivalent of 3 lb. kale, which is a liberal assessment, it is calculated that sprout would have to be produced for 27s. 6d. per ton to compete economically with kale at 20s. And kale can usually be produced for 15s. per ton.

At Hawkesbury College, it is stated, 1 ton of fodder, costing between £10 and £11, would provide "green" feed for 100 pigs for 11 days, while the same number could be fed over an equal period with green barley and lucerne for £1 to £1 10s.

The Auchincruive report presents no detailed estimate of cost

but says "in the light of our experience . . . this should not exceed £4 per ton."

The value of sprout fodder is assessed in the following way. The results of Experiment C are rejected: only 20 lb. swede replacement tests are included; the control average liveweight increase is taken as 16·3 lb. per week and the sprout average as 20 lb. The difference, 3·7 lb. per week for 12 weeks, is 44½ lb., and this at "quality subsidy" price (52s. per cwt.) is valued at 20s. The amount of sprout fed per bullock was 6¾ cwt., giving a value for sprout of roughly £3 per ton.

The saving in swedes of 15 cwt. is then assessed and, at 15s. per ton, is 11s. 3d. Taking this as the cost of 6¾ cwt. sprout, the swede replacement value is 33s. 4d. per ton. If swedes cost 20s. per ton, the swede replacement value is 44s. 5d. per ton.

These two together, £4 13s. 4d. or £5 4s. 5d., "have a monetary value considerably greater than the cost at which sprout can be produced."

In addition, it is suggested that £1 should be added as the saving in feeding costs (3 weeks) due to the more rapid fattening. This is, however, an alternative, not an additive saving, since it is not possible to have a surplus live weight increase and shorten the fattening period at the same time.

Since the question of value and cost of production in this definitely positive set of tests may affect decisions as to whether extensive repeat experiments are, or are not, to be made, the following check calculations have been made from the data on page 22.

1. Experiments in which 20 lb. swedes were replaced by sprouted fodder, excluding Experiment C—

	£	s.	d.
Av. excess liveweight, 0·49 lb. daily for 12·8 weeks = 43·9 lb. at 52s. per cwt. . .	1	0	5
Swedes saved, 20 lb. daily for 12·8 weeks = 1792 lb. at 15s. per ton	0	12	0
Maximum value of sprout fed, 9 lb. daily for 12·8 weeks = 806·4 lb.	1	12	5
Maximum value of sprout per ton .	4	10	0

2. All experiments—

	£	s.	d.
Av. excess liveweight gain, 0·39 lb. daily for 12·7 weeks = 34·67 lb. at 52s. per cwt.	0	16	1
Swedes saved, 20 lb. daily for 12·7 weeks = 1778 lb. at 15s. per ton	0	11	11
Maximum value of sprout fed, 9 lb. daily for 12·7 weeks = 800 lb.	1	8	0
Maximum value of sprout per ton	3	18	5

3. Value calculated from shortening fattening period, using same selected experiments as in 1—

The average excess liveweight gain of sprout bullocks was 43·9 lb. and the average daily rate of gain 2·82 lb. If the rate of liveweight gain were uniform throughout the period this would mean that the experimental bullocks would attain the same final weight as the controls in 15·6 days less, but, since the rate of gain is always higher at first and less towards the end of the fattening period, it seems not unreasonable to base this calculation on the Auchincruive estimate of a saving of three weeks.

The fattening period would then be 68·5 days.

	£	s.	d.
Swedes saved, 20 lb. per day = 1370 lb. at 15s. per ton	0	9	2
Rations for 21 days saved	1	0	0
Maximum value of sprout fed, 9 lb. daily for 68·5 days = 616·5 lb.	1	9	2
Maximum value of sprout per ton	5	3	0

This is slightly above the cost of production calculated above.

To all of these estimates a percentage should be added for the first ten days in which the apparatus is running without yielding any crop. If the process were used, say for 200 days in the year, roughly 5 per cent. should be added to the cost of production.

The above estimates of the cost of production of sprouted fodder do not include the possible additional cost of providing efficient

insulation or of laying a concrete floor and installing a water supply, or of materials for cleaning and sterilising trays and tank. The total cost will therefore vary from one centre to another and will depend on the initial facilities for setting up the plant.

GENERAL SUMMARY.

The patented apparatus and technique for producing sprouted grain for fodder are described and the difficulties encountered in practice discussed. An account is given of the changes in composition of the seed which occur during germination and growth of the seedling.

The results of feeding experiments with grain prepared by commercial methods with culture solutions and with grain germinated under simpler conditions with water are presented and summarised.

The evidence is, so far, negative as regards any special value of sprouted fodder for milk production, growth of calves, or pig fattening, but at one centre sprouted maize has given excellent results with fattening bullocks.

There is no conclusive evidence that germinated oats have any beneficial effect on reproduction in farm mammals.

The use of germinated grain in rations, not containing *fresh* green food, has been found to increase egg production and the fertility and hatchability of eggs. The effect on hatchability is correlated with decrease in porosity of the shell.

None of the known changes in composition of the seed on germination can, at the moment, be correlated with the beneficial effects in beef production. Nor can the increased rate of live weight gain be attributed to improvement in digestibility. The effect on hatchability of eggs may be correlated with an effect on calcium metabolism and calcium content of shell. It might also be correlated with the increase in riboflavin, which occurs in germination, since riboflavin deficiency has been shown to affect the viability of the embryo. These possibilities are relatively simple subjects for further study. No line of further investigation, other than confirmatory, is obvious for beef production.

Estimates are presented for cost of production of sprouted fodder with special patented apparatus and nutrient solutions. The cost will vary with the type of apparatus used, and with the initial facilities (water, heating, insulation) available. Whether, in practice, it will be able to compete against common fodder or root crops will depend on the price at which these can be produced.

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APPENDIX I.: PATENT SPECIFICATION WITH COMMENTS.

PATENT SPECIFICATION.

Convention Date (Germany) : Nov. 1, 1930.
Application Date (in United Kingdom) : Nov. 2, 1931. *No.* 30,335/31.
Complete Specification Accepted : Aug. 4, 1932.

Complete Specification.

Improvements in or relating to the Manufacture and Use of Nutrient Solutions for Accelerating the Germination and/or Growth of Seeds and Plants.

I, Paul Spangenberg, a German citizen, of Hessestrasse 25, Eisleben, formerly of Berlin-Wilmersdorf, Germany, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

The present invention relates to improvements in or relating to the manufacture and use of nutrient solution for accelerating the germination and/or growth of seeds or plants.

It has previously been proposed to subject seeds to artificial germination by means of nutritive substances such as solutions of super phosphate containing small portions of potassium phosphate, ammonium chlorate and other substances.

It is an object of the present invention to provide a method of manufacturing a nutrient salt solution by means of which the germination and growth of seeds without earth can be accelerated artificially to a much greater extent than has been possible hitherto.

According to the present invention I provide a method of manufacturing a nutrient solution for accelerating the germination and/or growth of seeds or plants characterised by incorporating one or more nitrogenous inorganic substances including a nitrogen containing acid with one or more carbon containing organic substances in aqueous solution.

According to the present invention also I provide a method of treating seeds to accelerate the germination and/or growth thereof characterised by placing the seeds in a thin layer in a container having means for passing liquid therethrough, covering the seeds completely with a solution produced by the above method and subsequently irrigating the seeds with reduced quantities of solution so that only the roots of the topmost seeds are covered.

In this process air and light are preferably excluded or the air may be replaced by a nitrogen or carbon containing gas. The germination is favoured if the seeds are first exposed to irradiation for example by rays from a quartz lamp. Suitable nitrogen containing acids are for example nitric acid and nitrous acid. Suitable constituents of the solution are for example, lime, sugar, nitric acid, urea and potassium phosphate. The lime serves particularly as a fertiliser, the sugar serves as a carbon carrier for the cellular structure of the plant, and the nitric acid and urea serve to transmit nitrogen. It will be understood of course that the lime

need not be present as such in the final product but may be present as calcium nitrate owing to the action of the nitric acid.

In order that the invention may be well understood, the following preferred method of carrying out the invention will now be given by way of illustration only.

By way of example a solution may be prepared using the following constituents in the following proportions :

	grams
Lime	100
Sugar	500
Water	200
Potassium phosphate, preferably dibasic	500
Free nitric acid	200
Water	500
Urea	100
Boron	2
Water	500

The first step consists in disintegrating the unslaked lime and mixing it with the sugar, whereupon 200 grams of water are slowly added to this mixture so as to slake the lime and cause the exothermic heat set free thereby to convert the sugar into caramel. The substance thus obtained represents a pastelike or gelatinous mass in which no solid constituents should be found.

Then the nitric acid is added, and the considerable heat developed thereby causes the gelatinous mass to dissolve into a liquid to which the potassium phosphate is added, the addition of the latter constituent being preferably effected alternately with that of additional 500 grams of water before the solution has cooled down. By slow stirring the thick liquid can be kept in a less viscous condition, the 500 grams of water being added during the stirring or afterwards.

According to the purity of the lime, a further addition of nitric acid up to 150 grams can be made to further the solubility of the lime. A larger portion of nitric acid will prevent the solution procured from this mixture with water for the treatment of the seeds from acquiring a slimy state so as to render subsequent rinsing of the germinated seeds or vegetable matter obtained unnecessary.

Urea and boron are added next, it being possible to substitute manganese for boron. In order to prevent subsequent hardening of the gelatinous paste, an additional quantity of 500 grams of water is added, or urea and boron may be dissolved first in a part of the remaining water and then added to the mixture. The jelly thus procured may be kept in suitable containers with the air excluded. For extended storing a preservative may be added. Any suitable preservative may be employed such as one of the kind used for preserving jelles and viscous liquids, for example salicylic acid. In order to prevent the growth or formation of moulds when using the diluted solution, a dilute aldehyde solution such as formaldehyde solution may be added to the prepared treating solution. The nutrient salt solution resulting from the composition stated above is suited particularly for accelerating the germination and growth of maize, and the constituents of the composition may be varied for other kinds of seed. To illustrate the comprehensive character of the applicability of the invention, the examples stated below give the compositions for use in treating a few other seeds.

CONSTITUENTS OF A SOLUTION FOR LUPINES.

	grams
Lime	500
Sugar	200
Nitric acid	100
Superphosphate	1000
Chlorate of manganese	5
Ammonium phosphate	10
Potassium phosphate	50
Albuminous substances soluble in water	25
Potassium silicofluoride	5
Water	3000

CONSTITUENTS OF A SOLUTION FOR SOYA BEANS:

similar to the above.

CONSTITUENTS OF A SOLUTION FOR OATS:

	grams
Basic nitrate of lime	1000
Sugar	400
Nitric acid	200
Potassium chloride	250
Magnesium sulphate	250
Ferrous sulphate	20
Albuminous substances soluble in water	15
Water	2000

CONSTITUENTS OF A SOLUTION FOR RYE:

	grams
Lime	1000
Sugar	500
Nitric acid	100
Calcium phosphate	250
Ammonium sulphate	250
Potassium chloride	250
Albuminous substances soluble in water	15
Potassium silicofluoride	5
Citric acid	5
Ferrous sulphate	10
Water	2000

According to the invention also the processes of germination and growth can be aided by adding soluble decomposition products of albuminous substances of animal or vegetable origin to the inorganic nutrient salts, as illustrated in the foregoing examples. These products of decomposition are organic building elements for the cells of the plant. Albuminous decomposition substances artificially produced such as is the action of sulphuric or hydrochloric acid or of enzymes are also cell stimulants for artificially influencing growth. The albumen from which these decomposition products are procured may be obtained from meat, casein, lactalbumin or the like, or from oil-free plant seeds. For example, if lupine seed is to be cultivated, the albumen of the lupines is preferably decomposed in any suitable way, and the decomposition products are, dissolved in water, added to the inorganic salts. From the chemical point of view, the decomposition substances may range from peptone to amino acid. It has been found that certain medicinal chemicals, such as iodine as such i.e. in solution or in the form of its salts for example potassium iodide, may be added to the solution without the least trouble and will be absorbed readily by the germinating plant in the nutrient solution described. By way of example about 2 gms. of iodine may be incorporated with the quantities of materials of the first example. This is extremely important, as it will permit, by rapid artificial cultivation, to produce food plants for man or beast, which are of great value to the organism. The composition of the nutritive substance of the plant can be determined by a suitable composition of the

nutrient solution. If vegetable fodder containing a very high percentage of phosphorus is to be produced, a considerable portion of potassium phosphate must be added during the preparation of the nutrient salt solution having the composition mentioned. If the fodder is to contain iron, an iron salt should be one of the constituents. In the same manner any possible harmful influence on the organism of man and animal can be prevented.

A nutrient substance according to the invention is used in the following way :

The seed is placed in flat layers without earth into suitable containers, such as watertight boxes having a regulatable discharge outlet. To facilitate attendance and save space, the boxes may be combined into cabinets by being placed side by side or on top of one another. For the daily watering of about 200 kg. of seed thus arranged 50 to 80 grams of the nutritive substance prepared are added to approximately 400-500 liters of water. The treatment should preferably be carried out while light and air are excluded. On the first day, watering with the solution stated should continue for about 10 hours. During the next few days irrigation should take place three times a day for about half an hour each. The boxes are preferably closed to prevent as much as possible the entrance of light and air. It will then be found that development of heat is an attendant phenomenon of growth, which, owing to its favourable effect, should not be interfered with by airing, as might happen during watering. The level of the solution within the boxes is chosen so that on the first day the seed layer is fully covered by the solution, but during the following days when the roots have grown downwards the solutions need reach only up to the lower ends of the roots of the topmost seeds. In the course of time the strength of the solution may be varied by concentration or dilution according to the nature of the seed and the purpose for which the product is to be used. If the seed is exposed for about 3 to 10 seconds prior to watering to radiation, by means of quartz lamps for instance, conditions for rapid germination will be improved. To further the growth carbonaceous or nitrogenous gas may be introduced into the boxes.

Owing to the watering and other treatment described, effective germination of the seed and growth of the plant will take place in a surprisingly quick way. Out of a seed layer 4 to 7 centimeters high will come after about 8 days a layer having approximately a height of 40 centimeters, which consists of a firm mass of roots, blades or leaves grown together, so that it can be removed as a solid block from its container after the period of growth is over. It is a remarkable fact that the grain of the seed is retained and quite firm after the treatment. Therefore, the vegetable layer can be used in this condition, without requiring cleaning and without waste, as fodder for animals, according to the seed employed for the germination and growth process. Experiments made with maize, cotton seed, lupines, common purple trefoil, soya beans and other seeds were very successful. The leafy portion can be removed from the seed and root portions and used in a suitable manner as raw diet for human beings. The invention is of very great importance for producing feeding stuff. Regardless of

the time of the year, fresh green fodder will be available whenever desired, so that it becomes possible to dispense entirely with hay as fodder which readily gets mouldy when stored and thus may cause disease. Furthermore, the feeding stuff may be selected with a view to feeding animals for the production of either meat or milk. The importance of the invention resides in the rapid cultivation of plants, particularly for obtaining green fodder at a season when Nature does not offer it. By applying the invention fresh food and fodder can be produced within about 5 to 8 days without tilling the soil and without being dependent on more or less favourable weather conditions. Hospitals or dietetic establishments in particular will be capable of producing on their own premises for dietetic treatment fresh vegetable foodstuffs containing certain nutritive or curative substances, such as iodine, and will be able to control the process completely.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is :—

1. A method of manufacturing a nutrient solution for accelerating the germination and/or growth of seeds or plants characterised by incorporating one or more nitrogenous inorganic substances including a nitrogen containing acid with one or more carbon containing organic substances, in aqueous solution.

2. A method as claimed in claim 1 in which the nitrogen containing acid is nitric or nitrous acid.

3. A method as claimed in either of the preceding claims in which sugar is the organic substance or one of the organic substances employed.

4. A method as claimed in any of the preceding claims in which unslaked lime in finely powdered condition is intimately mixed with sugar, water is added so as to slake the lime and by the heat generated to convert the sugar to caramel so that a gelatinous or pasty mass results which is dissolved to a liquid state by addition of nitric acid.

5. A method as claimed in any of the preceding claims in which soluble artificially produced degradation products of albuminous bodies of animal or vegetable origin are added to the inorganic nutrient substances.

6. A method as claimed in claim 5 in which the degradation products are derived from albuminous bodies occurring in plants of the same kind as those for which the nutrient solution is intended.

7. A method as claimed in any of the preceding claims in which the raw constituents employed comprise major quantities of unslaked lime, sugar, nitric acid, urea and potassium phosphates.

8. A method as claimed in any of the preceding claims in which iodine as such or in the form of iodide salts is incorporated in the solution.

9. A method as claimed in any of the preceding claims in which the contents of the solution such for example as the contents of iron, iodine, phosphorus are determined according to the plants to be treated and the purposes for which the latter are intended.

10. A method of manufacturing a nutrient solution for accelerating the germination and/or growth of seeds or plants substantially as described.

11. A solution for accelerating the germination and/or growth of seeds or plants when prepared by a method

as claimed in any of the preceding claims.

12. A method of treating seeds to accelerate the germination and/or growth thereof characterised by placing the seeds in a thin layer in a container having means for passing liquid therethrough, covering the seeds completely with the solution claimed in claim 11 and subsequently irrigating the seeds with reduced quantities of solution so that only the roots of the topmost seeds are covered.

13. A method as claimed in claim 12 in which the first irrigation is continued for about 10 hours on the first day of treatment and the subsequent irrigations take place for periods of about ½ hour three times a day on the following days.

14. A method as claimed in either of claims 12 or 13 in which before irrigation the seeds are subjected for a short time to irradiation for example by means of a quartz lamp.

15. A method as claimed in any of claims 12 to 14 in which air and light are excluded during irrigation.

16. A method of treating seeds to accelerate germination and/or growth thereof substantially as described.

17. Seeds or plants for animal or human food when treated by a method as claimed in any of claims 12 to 16.

Dated this 2nd day of November, 1931.

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COMMENTS.

(A full account of water culture of plants will be found in: Miller, E. C., *Plant Physiology* (32), on which the following comments are based.)

There can be no possible reason for excluding air. Indeed regular aeration of the roots in water cultures is considered essential to their success, and the plants in question here, e.g., corn, oats, soya beans, give marked responses to aeration.

With regard to the apparently elaborate and yet indeterminate prescriptions for culture solutions given here, it may be stated, (*a*) that none of these contain all the substances necessary for plant growth; (*b*) that the seed itself supplies all the necessary organic materials for growth to the stage at which the plant (under normal conditions) begins to synthesise from the soil and air; (*c*) in water culture simple "three-salt" solutions have been found to give as good results as much more elaborate mixtures.

The proportion of these three salts found to be "best" for different plants varies slightly with species, temperature and frequency of renewal, but "the concensus of opinion among workers in plant nutrition at the present time is that there is a wide range of solutions in regard to concentration, composition and proportions of components in which plants will thrive equally well and that the response of plants to any solution will depend to a great extent upon the environmental conditions under which they are growing."

The addition to the culture solution of organic compounds, sugar, urea, "albuminous substances soluble in water," citric acid, is certainly unnecessary

and of doubtful value. It is definitely established that green plants can grow to maturity if supplied only with the necessary inorganic salts in sufficient quantity. Sugars and organic acids can be absorbed and used in respiration, but there is no evidence of any benefit; organic nitrogenous compounds may supplement, but certainly cannot replace, inorganic nitrogen salts in plant nutrition, and, even if certain organic nitrogenous compounds were proved to have a special growth promoting influence as plant vitamins (which is not here suggested), it is certain that the seed would supply all that is required for the short period of growth in question.

Manganese and boron are not interchangeable. A trace of each is necessary; more than a trace of boron is harmful.

The composition of salt solutions used in water culture of tomatoes and other plants (the plants growing to maturity) are given by Templeton and Watson (45). The following is one used by them :—

Monoammonium phosphate ($NH_4H_2PO_4$)	0·121 gm./litre.
Potassium nitrate (KNO_3)	0·644 ,, ,,
Calcium nitrate ($Ca(NO_3)_2 . 4H_2O$)	0·095 ,, ,,
Ammonium nitrate (NH_4NO_3)	0·098 ,, ,,
Magnesium sulphate ($MgSO_4 . 7H_2O$)	0·368 ,, ,,

Minor elements have been supplied as Hoaglands " A-Z " solution, but if commercial trade salts are used, the following addition to the above solution should be satisfactory :—

Boric acid (H_3BO_3)	1·836 mgm./litre.
Manganous chloride ($MnCl_2 . 4H_2O$)	1·18 ,, ,,
Potassium permanganate ($KMnO_4$)	1·12 ,, ,,
Sodium silicate (Na_2SiO_3)	1·299 ,, ,,
Ferric citrate ($C_6H_5O_7Fe . 3H_2O$)	19·26 ,, ,,

It is true that the iodine content of the crop may be greatly increased by addition of iodine to the culture solution, but it is true only within narrow limits that the phosphorus and iron contents can be increased. Absorption of such constituents from the solution is selective, and analytical data would be required to show whether a significant difference can be produced by increasing the concentrates of phosphorus and iron over that which produces optimum growth, or can be produced without inhibition of growth.

It is impossible to imagine how the introduction of carbonaceous or nitrogenous gas (which would inhibit respiration) is to promote growth, especially in etiolated seedlings in which photosynthesis of carbohydrate from atmospheric carbon dioxide has not begun.

The " remarkable fact " that " the grain of the seed is retained and quite firm after the treatment " is in accordance with common experience with such large seeds as are here in question. The stored material far exceeds in amount the requirement of the seedling. (See also text, p. 10.)

It is unjustifiable to call a crop " fresh green fodder," of which only 12 per cent. (see p. 10) consists of shoots and these etiolated, not green. It is expressly stated that light shall be excluded.

APPENDIX II.: PATENT SPECIFICATION WITH COMMENTS.

Application Date : May 30, 1934. *No.* 16172/34.
,, ,, *May* 30, 1934. *No.* 16173/34.
,, ,, *June* 2, 1934. *No.* 16501/34.
One Complete Specification Left : May 29, 1935.

COMPLETE SPECIFICATION.

Improvements in or relating to a Method for Raising Plants from Seed

We, BARON GERHARD VON SKRBENSKY, a German Citizen, of Rheinstrasse 22, Zeuthen, Province of Brandenburg, Germany, and ALFRED WALLACE WALLACE-TURNER, a British Subject, of 1, Albert Place, London, W. 8, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement :—

This invention is for improvements in or relating to a method for raising plants from seed and deals with the raising of plants from seed with or without the presence of soil.

There have previously been described, e.g. in specification No. 9396/03 processes for the recovery of by-products (including ammonium sulphocyanide) from the purification of coal gas and the use of these by-products as fertilisers. It has also previously been proposed to include ammonium sulphocyanide in a disinfectant fertiliser for application over the soil preferably before or during the fall of rain.

It is an object of the present invention to provide a method for raising plants having a feeding value from seeds with or without soil which method produces plants of greater nutritive value and containing greater amounts of accessory food factors and of substances increasing resistance to disease in the consumer than such plants have hitherto contained. Thus, plants raised by the present process, particularly when raised in the absence of soil, may be employed as one of the constituents of a balance ration for farm animals.

Among the plants to which the present method may be applied with advantage may be mentioned cereals such as maize, wheat, oats and barley, papilionaceous plants such as peas and beans, tubers such as potatoes, and plants such as tobacco which are normally difficult to raise in temperature zones. For many years agricultural chemists have investigated with varying degrees of success methods of raising plants from seed without soil. Broadly speaking, such methods have involved the spraying or irrigation of the seeds with liquid feeding media containing in solution such agents as are necessary for germination and growth.

Research has now disclosed the fact that successful germination and growth are dependent, to a very large degree, on the composition of the liquid media employed and furthermore that if the plants raised by such methods are used as fodder for animals, the value of the fodder

both for nourishment and for the prevention of disease is dependent on the employment of even very small quantities of agents which impart to the fodder itself the power of stimulting in the animal certain hormones, glands or like organs, the function of which it is important to maintain in a state of activity.

It has been ascertained, for example, that certain diseases in animals, such as cancer, may arise from the nature of their foodstuffs and it is particularly desirable to produce foodstuffs which give to animals a natural resistance against such diseases.

Further, it is believed that the particular substances which confer resistance to disease, e.g. to goitre and cancer, may be transmitted to the consumers of the flesh or milk of animals fed on fodder raised in accordance with the present invention.

The present invention includes a process for raising plants from seeds with or without soil by treatment of the seeds with an aqueous liquid having nutrient materials dissolved or suspended therein and wherein such nutrient material includes a salt of sulphocyanic acid in a proportion not greater than 0·2 % on the weight of the solid content of the feeding liquid. The salt of sulphocyanic acid may be an alkali salt for example the sodium or potassium salt. In one preferred form of the invention the salt may be ammonium sulphocyanate.

In one method of carrying the invention into effect the seeds are first treated with water for example for a period of 12 to 24 hours and the water is then replaced by the liquid feeding medium. Both the preliminary treatment with water and the actual germination and growth of the seeds are carried out preferably at a temperature of the order of 18 to 24° C. The seeds are preferably arranged in perforated trays in a layer one to three seeds thick and the feeding liquid is preferably fed to the rootlets of the plants either in a continuous stream or intermittently. When the feeding liquid is changed at intervals it is desirable that the change should take place at least once in 24 hours. The seeds are preferably maintained undisturbed throughout the period of their growth and as the seeds sprout the level of the feeding medium is reduced so that only the ends of the rootlets are immersed therein.

It has been found that the feeding liquid may with advantage contain a proportion of iodine salts and in one preferred case the proportion of iodine salts is of the order of 0·3 % on the weight of the solid content of the feeding medium.

The present invention may with advantage be applied to the rapid raising of plants in the presence of soil, the germination and early stages of growth being carried out in the presence of the aqueous feeding medium. This modification of the process is of importance when it is desired to raise plants to a state of maturity requiring the development of root and stem which would only be attained when the plant is in soil. In this form of the invention the seeds are treated with an aqueous feeding liquid until germination has taken place and the first leaves have appeared and the plant is then transplanted to soil. Alternatively, the seeds may be planted from the first in soil and subjected to spraying or irrigation with a feeding liquid until the first leaves have appeared when

they may be transplanted and the feeding discontinued. This form of the invention may be applied with particular advantage to the growing of tobacco, of root crops such as potatoes and of hops. In the case of tobacco, seeds may be planted in soil maintained with a moisture content of approximately 50 % and at a temperature of about 30° C. while treated with a feeding liquid and exposed to sunlight and/or to irradiation with ultra-violet rays. When the first leaves appear the plants are transplanted to the site in which they are to be raised to maturity.

Potatoes may be raised to a certain state of maturity by growing them in soil in the dark and treating them with a feeding liquid but in order to bring them to full maturity they are raised at a temperature about 20° C. in soil in the presence of sunlight and/or ultra-violet radiation, the soil being kept moist with the feeding liquid and the plants transplanted when the first leaves appear.

In a further form of the invention the growing seeds are exposed to sunlight or ultra-violet radiation continuously and in order that sunlight may be utilised to full effect the chamber in which the plants are raised is provided with glass permeable to ultra-violet radiation.

The feeding liquid is preferably applied to the soil from above and below i.e. by a combined irrigation and spraying process in order to ensure a uniform moisture content throughout.

The seeds are conveniently planted in the soil to a depth equal to twice the thickness of the seed and if desired the feeding may commence with water or a dilute solution of the nutrient material, the concentration being increased as the seed germinates.

It will be understood that it is within the scope of the invention to raise plants to maturity without transplanting from seed planted in soil by feeding them with a nutrient liquid at an elevated temperature and by admitting light to the plants and/or radiating them with ultra-violet rays. Further, the seeds planted in soil and fed with a feeding liquid may have been previously germinated by feeding with a similar liquid in the absence of soil.

The necessary precautions should, of course, be taken when transplanting plants raised at elevated temperatures to sites out of doors.

Following are descriptions by way of example of methods of carrying the present invention into effect :—

Example I.

This example describes a typical feeding medium for use in raising seeds with or without soil. A mixture of 10 kg. of potassium nitrate, 5 kg. of Norwegian saltpetre, 2 kg. of sodium phosphate and 1 kg. of magnesium sulphate are ground together with 25 grms. of ammonium thiocyanate and relatively small amounts of iron and calcium compounds and soluble iodides and iodates and dissolved in tap water to make a concentrated solution and is employed in diluted form for the feeding of plants either with or without soil. The solution may contain in addition proportions of urea and sugars such as cane sugar, dextrose and lactose.

The composition of the liquid feeding medium may vary somewhat with the particular plants which are to be grown.

EXAMPLE II.

This example sets out one method of growing maize from seed without soil. The maize is spread in a layer about 1 or 2 grains thick on a perforated metal tray or similar supporting surface and is immersed in running tap water for 18 to 24 hours. At the end of that time the water is replaced by an aqueous feeding medium of the type set out in Example I and having the composition :—

100	grams potassium nitrate
10	grams normal sodium phosphate
5	grams magnesium sulphate
10	grams urea
0·2	gram ferric citrate
1	gram calcium sulphate
3	grams of a mixture in equal proportions of lactose, glucose and saccharose

Ammonium sulphocyanide in amount not exceeding 0·2 % on the weight of the solid content of the feeding liquid and iodine salts in amount not exceeding 0·3 % on the weight of the solid content of the liquid.

The seeds are treated with the above medium by running the liquid through the supporting trays. The level of the liquid is reduced as the roots grow and is kept just above the ends of the rootlets. The temperature is maintained throughout at between 18° and 24° C. At the end of 10 days or so the maize plants reach full growth (about 30 cms. in height depending on the conditions) and may be used as fodder with the addition of roughage such as hay or straw. The plants thus produced are rich in accessory food factors and therapeutic principles having prophylactic properties and these desirable characteristics are transmitted in the case of animals such as cows to their milk.

Sudden changes in the concentration of the aqueous feeding medium must be avoided in order that the rapid and continuous growth of the plant may not be interrupted.

EXAMPLE III.

This example illustrates the growth of seeds with the aid of soil. Tobacco seeds are sown to a depth about twice the thickness of the seed in a light soil rich in humus. The soil is in a layer about 20 cms. thick and is contained in a perforated tray standing within another tray to which feeding liquid may be supplied. Means are also provided for spraying feeding liquid on the surface of the soil, the total amount of liquid supplied being sufficient to maintain the moisture content of the soil at about 50 %. The trays are surrounded by glass walls permeable to short wave radiation e.g. blue glass and the apparatus is exposed to sunlight by day and to the radiation from a mercury vapour lamp by night and when there is no sunshine. The temperature of the enclosure is maintained at about 30° C.

The feeding liquid consists of 1 grm. of the following mixture dissolved in 5 litres of water :—

103	grams potassium nitrate
10	grams normal sodium phosphate
5	grams magnesium sulphate
5	grams urea
0·2	gram ferric citrate
1	gram calcium sulphate
3	grams glucose, lactose and saccharose in equal proportions
0·2	grams ammonium sulphocyanide

(The ammonium sulphocyanide may, if desired, be replaced by any other soluble sulphocyanide.)

The concentration of the liquid may later be increased to 2 to 3 grms. of mixed solid per 5 litres of water. In two to three weeks, when the rootlets are well developed and the first green leaves appear the plants may be transplanted. Alternatively, if the enclosure is of sufficient size the tobacco plants may be grown therein to maturity i.e. to the harvesting stage without transplanting.

Example IV.

Seed potatoes are planted in a layer of soil about 30 cms. deep, in an apparatus similar to that described in Example III, and are maintained at about 20° C. The feeding liquid is substantially the same as that employed in Example III.

When new potatoes only are required treatment with sunlight or artificially produced ultra-violet radiation may be reduced in amount or omitted altogether.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is :—

1. A process for raising plants from seeds with or without soil by treatment of the seeds with an aqueous liquid having nutrient materials dissolved or suspended therein wherein such nutrient material includes a salt of sulphocyanic acid in a proportion not greater than 0·2 °/₀ on the weight of the solid content of the feeding liquid.

2. A process as claimed in Claim 1 wherein the salt of sulphocyanic acid is an alkali salt.

3. A process as claimed in Claim 2 wherein the salt of sulphocyanic acid is ammonium sulphocyanate.

4. A process for raising plants from seeds with or without soil as claimed in any one of the preceding claims which comprises first treating the seeds with water and subsequently replacing the water by a liquid feeding medium.

5. A process as claimed in Claim 4 wherein the seeds are soaked in water for 18 to 48 hours in a layer one to three seeds thick.

6. A process as claimed in any one of the preceding claims wherein the feeding liquid is changed at least once every 24 hours.

7. A process as claimed in any one of the preceding claims wherein the liquid feeding medium is maintained at such a level that it covers the ends of the roots of the plants.

8. A process as claimed in any one of the preceding claims wherein the seeds are germinated and grown at a temperature between 18 and 30° C.

9. A process as claimed in any one of the preceding claims wherein there is added to the feeding medium a proportion of iodine salts, for example of the order of 0·3 °/₀ on the weight of the solid content of the medium.

10. A process for raising plants from seeds which comprises treating the seeds with a liquid feeding medium by the process claimed in any one of the preceding claims and transplanting the seeds to soil as soon as the first leaves appear.

11. A process for raising plants from seeds with or without soil by feeding by a process as claimed in any one of the preceding claims

wherein the seeds are subjected to the influence of light and/or irradiation with ultra-violet rays.

12. A process for raising plants from seeds with or without soil substantially as described in any one of the specific examples hereinbefore set forth.

Dated this 29th day of May, 1935.

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COMMENTS.

The indications regarding the composition of the nutrient solution given here are clearer than those in Appendix I. Two comments only are necessary: (*a*) that the solution here specified does not supply all the substances necessary for the growth of plants and (*b*) that no evidence is offered regarding the special value of sulphocyanides. Some of the remarks on Appendix I are applicable also to this specification.

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